LIVERPOOL

GEOLOGICAL ASSOCIATION.

TRANSACTIONS.

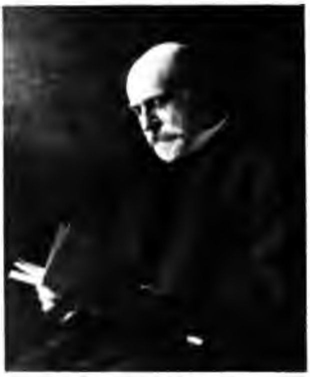
VOLUME II.

SESSION 1881-1882.

LIVERPOOL:
Published by Henry Young, 12, South Castle Street.

1882.

Price Three Shillings.



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INDEX.

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The Authors are alone responsible for the facts and opinions expressed in their Papers.

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FIELD MEETINGS AND EXCURSIONS—

ERRATA.

—:—

"IRON PYRITES," p. 51, line 29, for '*Great Britain*' read '*United Kingdom.*'
"RIVERS," .. ,, 39, ,, 9, ,, '*addition*' .. read '*edition.*'
——— .. ,, 40, ,, 2, ,, '*water*' .. read '*matter.*'

LAWS

OF THE

LIVERPOOL GEOLOGICAL ASSOCIATION,

Established 3rd June, 1880.

RULES PASSED 15TH NOVEMBER, 1880.

OBJECT.

The object of the LIVERPOOL GEOLOGICAL ASSOCIATION *is to promote the study of Geology and its allied Sciences.*

RULES.

I.

That every Candidate for membership shall be proposed and seconded by two members of the Association, and ballotted for at the next Ordinary meeting; and the consent of three-fourths of the members then present shall be necessary for the admission of such Candidate.

The proposal shall be made on Form A, which must be filled up and lodged with the Secretary one week before the meeting at which the Candidate is to be proposed. The proposal form shall be submitted to the Council, and the Secretary shall report to the members any remarks the Council may deem it expedient to make thereon.

II.

Every member shall pay an annual subscription of Five Shillings, payable on the 1st October, or in the case of a new member, within one month after election. Any member not paying the subscription within three Calendar months, after being twice informed by the Secretary that it is due, shall no longer be considered a member of the Association.

III.

The Officers of the Association shall be a President, Vice-President, Treasurer, Secretary, and five other members, who together shall constitute the Council to manage and direct the affairs of the Association. Five to form a quorum. The officers shall be elected at the Annual Meeting, to be held in October; retiring officers shall be eligible for re-election. Any vacancy occurring during the year shall be filled up by the Council.

IV.

The Treasurer's Financial Statement shall be presented to the Association, with the Annual Report, after having been duly audited by two members proposed, seconded, and elected at the last meeting of the Session.

V.

The Ordinary Meetings shall be held on the first Monday in each month, at Eight o'clock in the evening. The order of proceeding at such meetings shall be:—

1.—The ordinary business of the Association.
2.—Miscellaneous Communications.
3.—Original Papers or Communications, to be followed by discussion thereon.
4.—Announcement of business for the next meeting.

VI.

A Special Meeting may be called at any time by the Council; and they shall be bound to call such a meeting on receipt of a requisition signed by not less than ten members, stating the purpose for which the meeting is to be convened. Seven days' notice of a Special Meeting shall be given to every member, such notice to specify the business to be considered, and the meeting shall be held within twenty-one days after the receipt of the requisition. No other business shall be considered at a Special Meeting except that for which it has been called.

VII.

Field Meetings shall be held at places of Geological interest but none of the private business of the Association shall be transacted on such occasions.

VIII.

The votes on any question brought before the Association shall be taken by a show of hands, except those for the election of officers and new members, which shall be taken by ballot.

IX.

The Manuscript of every Paper read, or a clear and legible copy thereof, written on Foolscap, shall become the property of the Association, and shall be placed in the Library for the use of the members.

X.

In case of non-compliance with the Rules of the Association, or misconduct by any member, such member may be requested by the Council to resign. Failing to do so, the Council may bring the case before a meeting of the Association which shall deal with it as may seem expedient.

XI.

Every member may introduce a friend at any Ordinary or Field Meeting of the Association, provided, however, that no person qualified to become a member be admitted as a Visitor more than twice in the same year.

XII.

No addition to or change in these Rules shall be made, except by a majority of not less than two-thirds of the members present at a Special Meeting to be convened for that purpose.

LIVERPOOL GEOLOGICAL ASSOCIATION.

FORM A.

M ....

....

being desirous of admission to the Association, We, the undersigned, recommend h   as a proper person to become a Member.

Dated..................................18

Proposed by..

Seconded by ....

Date Proposed..18

Date Elected 18

Signature of Candidate..

....Secretary.

REGULATIONS FOR THE ADMISSION OF MEMBERS.

RULE 1.—That every Candidate for membership shall be proposed and seconded by two members of the Association, and balloted for at the next ordinary meeting; and the consent of three-fourths of the members then present shall be necessary for the Admission of such Candidate.

The proposal shall be made on Form A, which must be filled up and lodged with the Secretary one week before the meeting at which the Candidate is to be proposed. The proposal form shall be submitted to the Council, and the Secretary shall report to the members any remarks the Council may deem it expedient to make thereon.

RULE 2.—Every Member shall pay an Annual Subscription of Five Shillings, payable on the 1st October, or, in the case of a new member, within one month after election. Any member not paying the subscription within three calendar months, after being twice informed by the Secretary that it is due, shall no longer be considered a member of the Association.

LIVERPOOL

GEOLOGICAL ASSOCIATION.

ANNUAL REPORT,
1881.

LIVERPOOL GEOLOGICAL ASSOCIATION,

FREE LIBRARY, WILLIAM BROWN STREET.

Council.

PRESIDENT.

HENRY BRAMALL, M. INST. C.E.

VICE-PRESIDENT.

THOMAS SHILSTON, M.I.N.A.

MEMBERS OF COUNCIL.

THOMAS BRENNAN.

ISAAC E. GEORGE.

H. T. MANNINGTON.

DANIEL CLAGUE.

C. E. MILES.

TREASURER.

WILLIAM H. WALKER.

SECRETARY.

OSMUND W. JEFFS,

8, Queen's Road, Rock Ferry

THIS COUNCIL WILL CONTINUE UNTIL OCTOBER 1882.

LIVERPOOL GEOLOGICAL ASSOCIATION.

ANNUAL REPORT,

3rd October, 1881.

On retiring from office your Council beg to present the following Report.

Since the last Annual Meeting 26 new members have joined the Association, and there have been no withdrawals. The members now on the rolls number 53.

There have been held during the Session 10 Evening Meetings, at which Papers have been read and discussed on the following subjects:—

Inaugural Address, by the President.

The Giant's Causeway, by A. Quilliam.

Curious Natural Phenomena at Cephalonia, by Captain H. P. Shilston.

Analysis of a Salt found in a Colliery near St. Helens, by H. T. Mannington.

Climatic Changes, "Croll's Theory," by Thos Brennan.

The Rise and Progress of Geological Discovery, by O. W. Jeffs.

The History of Escarpments, by C. E. Miles.

Notes on the Brixham Bone Caves, by Thomas Shilston. M.I.N.A.

Isomorphism and Dimorphism as exemplified by Mineral Species. by Geo. Tate, Ph. D.

The Lower Carboniferous Deposits of Anglesea, by Isaac E. George.

Field Meetings have been held as follows:—

18th April,	1881,	at Matlock Bath.
6th June,	,,	,, Llandudno.
2nd July,	,,	,, Storeton Quarries.
1st August,	,,	,, The Wrekin.
20th August,	,,	,, Thurstaston Hill.

A number of the members availed themselves of an invitation by Mr. T. Brennan to join in a visit to Rose Bridge Collieries, near Wigan, on the 9th April; and also of the invitation of the Liverpool Geological Society to join their excursion to Dawpool on the 28th April.

An interesting feature of the evening meetings has been the exhibition of specimens belonging to the members, many of which have been very remakable and instructive.

All the Meetings of the Session have been well attended. The Field Meetings have afforded great gratification to those who have taken part in them, and the Council venture to hope that they have not been unattended with profit as exemplifying actual work in the field.

During the Session the following donations have been received:—

A set of Proceedings of the Liverpool Geological Society.

Abstracts of the Proceedings of the Geological Society of London, Session 1880-81, from Mr. G. H. Morton, F.G.S.

The Printing of the Transactions has been commenced, and is in progress.

The Council would remind the members of the arrangements made with respect to the publication of the Transactions, which are:—That every member reading a Paper is required to furnish an abstract of his Paper not exceeding six pages of ordinary foolscap writing, which will be printed at the cost of the Association, but the Association will undertake to print any approved Paper in full, on consideration that the author will pay at the rate of Two Shillings per printed page for all beyond the first four. The Association will also print illustrations to any Paper at the cost of the author. Every author of a Paper will receive 20 copies of the print of his Paper.

The Treasurer's Financial Statement having been duly audited in accordance with the rules is appended to this report. After providing for all liabilities there is still a small balance of Cash in hand of £2 1s. 10d.

At this Meeting the officers of the Association will require to be elected for the ensuing Session in accordance with Rule 3.

In congratulating the members upon the progress of the Association the Council desire to urge upon all the necessity of providing Papers and bringing forward interesting subjects for discussion. It is only by the interest manifested by each individual member that the success so far attained can be maintained.

LIVERPOOL GEOLOGICAL ASSOCIATION, *In Account with the Treasurer.*

FOR THE YEAR ENDING SEPTEMBER, 1881.

DISBURSEMENTS.

			£	s.	d.	£	s.	d.
1881.								
Sept. 30,	To	Attendant at Meetings	1	7	6			
,,	,,	Printing	6	1	9			
,,	,,	Postages & Incidentals	3	1	11	10	11	2
,,	,,	Balance				3	13	4
						£14	4	6

RECEIPTS.

		£	s.	d
1880.				
Oct. 31,	By Balance	1	9	6
1881.				
Sept. 30,	By Subscriptions. 1880-1, 51 @ 5/-	12	15	0
		£14	4	6

	£	s.	d
By Balance brought down......................	3	13	4
Two Subs. 1880-1, not yet received......	0	10	0
	£4	3	4
Less amount due for Printing..................	2	1	6
	£2	1	10

Balance, £3 13 4.

Audited and found correct,

C. C. MOORE.
J. E. JONES.

Liverpool, 3rd October, 1881.

W. H. WALKER, Treasurer.

LIST OF MEMBERS.

AUDEN, A. W., 54, Tiber Street.

BARUCHSON, ISAAC, 13, Granton Street.

BRAMALL, HENRY, M. INST., C.E., 3, Balmoral Road.

BRASH, MISS L. A., 8A, Grove Street.

BRENNAN, THOS., 37, Towson Street.

BROADHURST, MISS M. A., Glasgow.

BROADHURST, MISS E., Belmont Drive Newsham Park.

BROWNE, A. H., 33, Hampden Street, Higher Tranmere.

CAPON, R. M., L.D.S., 114, Vine Street.

CARTER, C. W., 4, Springfield, Everton.

CLAGUE, DANIEL, 70, Solway Street.

CHUBB, G. O., 133, Huskisson Street.

DAVIES, DAVID, 34, Landseer Road.

EDWARDS, GEORGE H., 2, Whitechapel.

ELIAS, O. H. 6, The Elms, Toxteth Park.

FOX, HERBERT, 29, Harland Road, Higher Tranmere.

GEORGE, ISAAC, E, 95, Cawdor Street.

GOULD, JOSEPH, 28, Bedford Place, Seaforth.

HALL, HUGH F., F.G.S., Greenheys, Grove Road, Wallasey.

HOWARD, J. D., 109, Christian Street.

JEFFS, O. W., 8, Queen's Road, Rock Ferry.

JONES, J. D., 72, Harrowby Street.

JONES, J. E., 18, South Hunter Street.

LESLIE, MISS L., 26, Oxford Street.

MANNINGTON, H. T., 224, Westminster Road.

MARTIN, WILLIAM Station View, Yew Tree Road, Walton.

LEWIS, GEO., 81, Everton Terrace.

MILES, C. E., 16, Willow Bank Road, Higher Tranmere.

MILES, W. H., 8, Clifton Road, Birkenhead.

MOORE, C. C., Jun., 123, Richmond Row.

MORRIS, JOHN, 6, Dingle Hill.

OWEN, MISS M. 20, Gibson Street.

PROCTOR, S. H., 65, Erskine Street.

QUILLIAM, A. 37, Zante Street.

READE, T. MELLARD, C.E., F.G.S., Park Corner Blundellsands.

ROBERTS, H. T. 41, North Hill Street.

ROBERTS, J. M. 20, Lowther Street.

ROWLANDS, T. V. Roseneath, Falkner Road, Egremont.

RUNDELL, T. W., Litherland Park.

SEMMONS, WILLIAM, 57, Gracechurch St., London, E.C.

SHARPE, GRANVILLE H., 96, Duke Street.

SHILSTON, CAPT. H. P., 1, Saltoun Terrace, Seacombe.

SHILSTON, MRS. H. P., 1, Saltoun Terrace, Seacombe.

SHILSTON, THOS., M.I.N.A., 1, Belgrave street, Liscard.

SHILSTON, MRS. THOS., 1, Belgrave Street, Liscard.

TATE, A. NORMAN, F.I.C., 9, Hackins Hey.

TATE, GEO. Ph. D., 96, Duke Street.

TAYLOR, H. B., 7, St. James's Road.

WALKER, W. H., Botanic View, Smithdown Lane.

WESTCOTT, H., 5, Falkner Square.

WILLIAMS, J. J., 19, Falkner Street.

WILLIAMS, MISS L., 101, Duke Street.

WILLIAMS, T. G., Moss Bank, Croxteth Road.

Abstract of Proceedings

OF THE

LIVERPOOL GEOLOGICAL ASSOCIATION.

SESSION 1881-82.

1st October, 1881.

A visit was made to the Owens College at Manchester, where Professor W. Boyd Dawkins met the party and explained the arrangement of the Geological collections, afterwards conducting them through the Museum, Lecture Rooms, Laboratories, &c.

3rd October, 1881.

The Annual Meeting was held this date, at the Free Library, Mr. H. Bramall, M. Inst., C.E., President, in the Chair.

The Annual Report and Treasurer's Statement of Accounts were read by the Secretary, and the Officers for the ensuing Session, 1881-82, were elected.

The following proposed at the last meeting on 5th September, were elected :—Miss M. Wigzell, Messrs. George Scott and L. C. Simpson.

The following were proposed as members :—Messrs. J. L. Hedley, H.M. Inspector of Mines, Chester; W. M. D. Smith, Holyrood Terrace, Edge Lane; Willem S. Logeman, M.R.C.P., Highfield, Rock Ferry; W. H. Quilliam, 49, Rufford Road; J. C. Jones, 82, Windsor Street.

Abstract of a Paper read, entitled—

"NOTES ON THE DRIFT DEPOSITS AT GARSTON,'

By Isaac E. George.

These deposits consist of Boulder Clay, and the more recent sands, &c., usually following the clay in the neighbourhood of Liverpool.

The cliffs extend for several miles to the south-east of Garston, but they are usually low, rarely reaching the height of 20 feet.

The most interesting section to be observed is immediately adjacent to the rifle targets. Here, the deposits stand in the following order:—First, the *Boulder Clay*, generally full of stones throughout and at this spot exhibiting in the face of the cliff a well marked seam of large pebbles extending horizontally for a short distance.

Next, a thin seam of *Peaty Sand*, covering the Boulder Clay at this point, but thinning out rapidly on each side. This deposit forms the roof of a long cavern which has been excavated in the Boulder Clay. Its thickness is very insignificant.

Above, it is succeeded by an important accumulation of *sand and gravel*, which here reaches its greatest observed thickness.

Where its thickness is about three feet, it is occasionally found to be indurated through the infiltration of iron. Small well rounded pebbles sometimes occur at its base.

In the Glacial drift are found numerous large boulders of granite, felstone, volcanic breccia, basalt, &c., whilst striated *pebbles are very* abundant.

Field Meeting, 5th November, 1881.

The excavations at the Gas Works at Linacre were visited, and the sections of Boulder Clay, &c., described by Mr. Thos. Brennan, who conducted the excursion.

By the courtesy of Mr. William King, the party afterwards inspected the existing Gas Works under the guidance of Mr. Wm. Cleland.

The following sections show the Drift Beds at this part:—

BORE No. 3.

	FT.	IN.
Soil and Sand..	6	2
Peat	0	2
Loamy Gravel	0	6
Clay	12	4
Gravel and Loam..........	0	4
Clay	11	10
Sand	0	8
Sandy Loam & Yellow Clay	2	6
Red Sandstone............	13	10
	48	4

BORE No. 4.

	FT.	IN.
Soil and Sand............	9	0
Peat	0	2
Gravel	0	6
Top Clay	7	6
Bottom Clay..............	11	9
Red Sandstone............	4	6
	33	5

LIVERPOOL GEOLOGICAL ASSOCIATION,

11th November, 1881.

At the Ordinary Meeting, held this date, Mr. H. Bramall, M. Inst., C.E., President, in the Chair, the following gentlemen, proposed on October 3rd, were elected as Members:—

Messrs. J L. Hedley, W. M. D. Smith, Willem S. Logeman, W. H. Quilliam and J. C. Jones.

Proposed as members:—Messrs. T. J. Moore, Curator of the Brown Museum, Liverpool; A. E. Lewis, Longton Villa, Rainhill; W. Grisewood, Liscard Park, Liscard; Thomas S. Hunt, 5, Westminster Street, Liverpool; George J. Robins, Ashton Cross, Newton-le-Willows.

Abstract of a paper read—

"THE FORMATION AND CHANGES OF MINERALS,"

By George Tate, Ph. D., F.G.S.

The author commenced by pointing out that Chemical Geology and Chemical Mineralogy have, within the last half century, undergone, like other sciences, a revolution; and he compared the old views regarding the origin of mineral veins with the modern ideas. Formerly veins were regarded as of igneous origin, and, in fact, many amateur geologists if questionedon the subject will be found also to hold this view, at the present time, their formation is generally ascribed to aqueous agencies.

Blum, Gustav Bischoff, Sandberger, Sorby, Zirkel and others have, by their labours, tended to bring these more perfect theories to substantiation. For such researches the highest skill of both the practical chemist and of the mineralogist is required, for the two chief lines along which these labours have been directed are in the examination of pseudomorphs and in the accurate chemical analyses of minerals and rocks.

The author explained that the object of the paper was to

illustrate in an elementary manner the theoretical and practical value of chemical analyses of rocks and minerals, and to show how the study of pseudomorphs has resulted in many discoveries of importance.

Some familiar instances of pseudomorphism were mentioned, including malachite after cuprite, where crystals of cuprite (protoxide of copper) had become transformed into malachite (carbonate of copper); copper pyrites after fahlore; cimolite after augite, (of Bilin), where the augite, with the gradual decomposition of the trap rock in which it rested, had been changed into hydrated silicate of alumina, the other chemical constituents of the augite having been dissolved and washed away.

As instances of decomposition closely allied fo this last the author explained the changes which the potash and soda felspars undergo; he showed how the greater stability of minerals containing silicate of potash as compared with those containing silicate of soda, was well exemplified by the different facilities with which these two minerals, orthoclase and albite, undergo decomposition. In the same rock soda felspar may be frequently distinguished from the potash felspar by the dull and decomposed appearance of the former, the latter still maintaining its lustre though exposed to the same conditions.

The formation of metalliferous veins was then described, and the attention of students was called to the connection between the chemical composition of minerals found in veins and the minerals found in the neighbouring rocks.

The author pointed out that micas, felspars and hornblendes have been frequently found to contain traces of heavy metals such as tin, lead, nickel, barium, &c. These facts, together with the occurrence of pseudomorphs, tend to prove the aqueous origin of metalliferous and other minerals, and also that these deposits have been formed by the dissolution of metallic substances out of the neighbouring rocks. Subsequent chemical changes have occurred whereby carbonates, oxides, sulphides, sulphates and other salts have been precipitated in veins. As an instance capable of being readily

demonstrated, the presence of apatite in trap rocks was shown, and the probable connection of this with phosphorite deposits was indicated.

The aqueous origin of minerals, such as quartz, mica, tinstone, &c., is clearly proved by the investigations of pseudomorphs, to which great attention should be devoted by all students of mineralogy.

The author concluded by referring to the possible and probable formation of many minerals by igneous agencies, but maintained that the majority of minerals found in veins are of aqueous origin.

Dr. Tate illustrated his paper by typical specimens of the minerals and pseudomorphs mentioned by him.

DISCUSSION.

In the course of the discussion which followed the reading of Dr. Tate's paper, the President mentioned the interesting discoveries in the old Roman well at Bourbonne-les-Bains, described by M. Daubrée. This well was 25 feet deep; the water is saline, and has a temperature of from 136° to 158° Fahr. At the bottom was found mud containing nuts, leaves, &c., and numbers of coins of bronze, silver and gold, ornaments, pieces of leaden frames, &c. Beneath the mud was a conglomerate of grey grit, with a few flints cemented together by mineral substances, and amongst which 24 distinct species of minerals were identified. Of iron minerals there were a hydrous silicate, pyrites and vivianite. Lead,—Anglesite, Cerussite, Phosphogenite and Galena. Copper,--Redruthite (in bright distinct crystals, often twinned), Pyrites (both crystallised and as blister copper), Bornite (in octahedrons and cubes) and Fahlerz (crystallised). Tin—appeared as a white oxide on the surface of some bronze coins. At this small depth and low temperature, and within the comparatively *short space of* sixteen centuries, the action of saline waters

had resulted in the conversion of metals into the mineral states in which they are found in veins.

The President also referred to some experiments described by M. Walthère Spring in the "Revue Universelle des Mines" last year, on the effects of great pressures on various substances at ordinary temperatures. As interesting in connection with mineral changes he mentioned that Charcoal in fine powder remained unaltered at the very heaviest pressure tried (20,000 atmospheres); but finely powdered Coal at a pressure of 6000 atmospheres is consolidated into a shiny block. Brown Peat too at a pressure of 6000 atmospheres becomes converted into a black hard shiny block, quite undistinguishable from coal, showing a laminated structure but no trace of its vegetable origin, and it yields a dull grey compact coke precisely like that from coal. Sulphur was experimented upon in its three states of prismatic (S. G. 1·96), plastic, and octahedral or native (S. G. 2.05). Under a pressure of 5000 atmospheres the prismatic becomes converted into the octahedral form, and its specific gravity is raised to 2.02. The plastic assumes the octahedral form under a pressure of 6000 atmospheres. The octahedral form when powdered readily rejoins at 3000 atmospheres and forms sound blocks. But perhaps the most remarkable result obtained was the effecting of chemical combination by simple pressure. Copper filings were mixed (cold) with powdered sulphur, and subjected to a pressure of 5000 atmospheres. They combined perfectly, forming Copper glance or Redruthite, with no visible trace of metallic copper. The contraction in the mass was from 138 volumes of the mixture to 100 volumes of the mineral. It would appear, however, from other experiments with substances, that *expand* in combining that combination in such cases is *sometimes* prevented by pressure.

The investigations of the American geologists into the structures of the Comstock Lodes have led them to the conclusion that these remarkable deposits are the results of Solfataric action, and that the materials filling the lodes or veins have been brought up from below, both in solution in hot springs and in metallic vapours. No other hypothesis seems so satisfactorily to account for the phenomena met with, and there is no evidence that any of the minerals now filling the veins have been derived by segregation from the enclosing rocks.

LIVERPOOL GEOLOGICAL ASSOCIATION,

5th December, 1881.

At the Ordinary Meeting, held this date, Mr. H. Bramall, M. Inst., C.E., President, in the Chair, the following gentlemen, proposed at the last meeting, were elected as members:—

Messrs. T. J. Moore, (Curator,) A. E. Lewis, W. Grisewood, Thomas S. Hunt and George J. Robins.

Proposed as members:—Messrs. Henry Young, 12, South Castle Street; R. L. Tapscott, 41, Parkfield Road, Princes Park; Alexander Brodie, 56, Hatherley Street, Princes Park.

DONATIONS.

The following donations to the Library were received.—

Transactions of the Edinburgh Geological Society, for 1880-81, from the Society.

Abstracts of Proceedings of the Geological Society of London, March to November, 1881, from Mr. G. H. Morton, F.G.S.

Annual Report of the Birkenhead Free Public Library, 1880-81, from Mr. Richard Hinton.

The following Paper was read—

"ON FOSSIL FOOTPRINTS,"

By Thomas Shilston, M.I.N.A.

A haziness of idea has been found to prevail regarding these interesting relics of a long past age. It has been endeavoured to ascertain in the remarks that follow, some facts which have been recorded as bearing on the subject. I heard of one enthusiastic young geologist on visiting Storeton, expecting to find *Cheirotherium Footprints* on the sides of the quarry, like a pattern on a wall paper; it is needless to observe such expectation was doomed to disappointment, and the student returned a wiser, if not a sadder student.

It is the more important for us, surrounded as we are by the Triassic formation, of which these footprints are so characteristic, to have clear ideas of how they were formed, what they imply, and what we may infer from them.

These fossil footprints are, then, impressions made by the

feet of birds, quadrupeds or reptiles on the soft, moist, yielding surface of mud or sand, over which they travelled, and with them may be classed ripple marks, rain pittings and sun cracks. These impressions have afterwards been filled in by deposition of material, held in suspension in water, so causing the print to be imperishably preserved, and show that, in some cases at least, the one operation must have quickly succeeded the other; the impression of the markings on the integument, or skin, has been beautifully preserved. The footprints are found, as we might have expected, imprinted in many pages of the stony record, notably in the Trias, also in the Carboniferous series of North America; and in the supposed Cambrian equivalent on that same continent.

Regarding the footprints of an animal called *Labyrinthodon*, (so named by Prof. Owen, from a section of its tooth exhibiting a series of irregular folds, resembling the labyrinthic windings of the surface of the brain,) a tooth found in Warwickshire was about one inch long, but the supposed entire length of a larger one, a portion of which was found in Germany, was 3½ inches and 1½ inches broad at the base. These footprints were first observed in the Bunter, at Hesseberg in Saxony, and bearing a close resemblance to these, others were found afterwards, close at our doors at Storeton, in Cheshire. They were referred for many years to a large unknown quadruped provisionally called *Cheirotherium*, (from Greek, *Cheira*, a hand, and *therion*, a beast,) its footprints bearing a resemblance to the human hand.

Professor Owen found from the remains of the various teeth, bones and footprints, that he could define three species of Labyrinthodon, and that in this genus the hind legs with feet were much larger than the anterior ones, the footmarks were more like those made by toads, than any other living animal, and Sir Charles Lyell says, "it was inferred with confidence that it must have been an air breathing reptile; from the structure of its nasal cavity, it must have respired after the manner of saurians, and may therefore have imprinted on the shore those footsteps, too firmly and distinctly *to have originated* from an animal walking under water."

The New Red Sandstone, as developed in Massachusetts and Connecticut is remarkably rich in footprints and ripple marked fossils.

According to Professor Hitchcock, the footprints of no less than thirty two species of bipeds and twelve of quadrupeds, have been already detected in these rocks. Thirty of these are believed to be those of birds, two of chelonians, four of lizards and six of batrachians. The tracks have been found in more than twenty places, scattered through an extent of nearly eighty miles, from north to south, and they are repeated through a succession of beds, attaining at some points a thickness of more than one thousand feet, which must have taken an extended period to form.

I make the following extract from Sir Charles Lyell, to show what grounds the geologist has for supposing these footprints to be really what they appear to be. He says "when I visited the United States, more than two thousand such impressions had been observed in the district above alluded to, and all of them were indented on the upper surface of the layers, while the corresponding casts, standing out in relief, were always on the lower surfaces of the strata. If we follow a single line of marks, we find them uniform in size, and nearly uniform in distance from each other, the toes of two successive footprints turning alternately right and left. Such straight lines indicate a biped, and there is generally such a deviation from a straight line in any three successive prints, as we remark in the tracks left by birds. There is also a striking relation between the distance separating two footprints in one series, and the size of the impressions, in other words, an obvious proportion between the length of the stride, and the dimension of the creature which walked over the mud. If the marks are small, they may be half an inch asunder; if gigantic, as for example, where the toes are twenty inches long, they are ocassionally four feet and a half apart. The bipedal impressions are for the most part trifid, and show the same number of joints as exist in the feet of living birds. Now, such birds have three phalangeal bones, for the inner *toe, four for the* middle, and five for the outer one; but the

impression of the terminal joint is that of the nail only. In some specimens besides impressions of the three toes in front, the rudiment is seen of the fourth toe, behind."

The matrix is not often fine enough to preserve an impression of the marking of the skin, or integument of the foot. In one fine specimen, however, this is the case, and Professor Owen, who examined this, found it to resemble the skin of the ostrich, and not that of a reptile. The enormous size of some of these footprints amazed the naturalists when first discovered. As the animals who made them must have had feet four times as large as an ostrich—at that time, however, the almost entire skeleton of the Diornis of New Zealand had not been discovered, which might have been sufficiently large to have made some of the largest impressions found. Sir Charles Lyell says, that the greater number of the American impressions agree so precisely in form and size, with the footmarks of known living birds, especially with those of waders, that we shall act most in accordance with known analogies, by referring most of them, at present, to feathered, rather than to featherless bipeds. Darwin, in his "Journal of the voyage of the Beagle," informs us that South American ostriches, although they live on vegetable matter, such as roots and grass, are repeatedly seen at Bahia Blanca, on the coast of Buenos Ayres, coming down at low water, to the extensive mud banks, which are then dry, for the sake, as the natives say, of feeding on small fish. So that a South American mud bank, in the present day, might have impressions of footmarks of bird, alligators, tortoises and frogs.

In 1851, Sir William Logan brought from the banks of the St. Lawrence, some impressions of footprints, together with many casts of others, peculiar in their nature; these were submitted by him to Professor Owen, who formed the opinion, that they were the trail of a species of articulate animal, probably allied to the Limulus, or King Crab. Between the two rows of foot tracks, an impressed median line, or channel, supposed by the professor to have been made by a caudal *appendage, (or tail)* rather than by a prominent part of the *trunk. The width* between the outermost impressions varies

from three and a half to five and a half inches. These impressions were found in rocks supposed to be equivalent to the Cambrian, of Britain.

I would mention, in passing, some fine specimens of the King Crab, are now to be seen at the Aquarium, at Southport, and if Professor Owen's opinion were correct, what a persistent existence this species must have had,—from the Cambrian to our time.

In Pennsylvania the footprints of a reptilian quadruped were described, some years ago, by Dr. King as being found in the coal measures of that district. Impressions of Lepidodendron, Sigillaria, Stigmaria, and other carboniferous plants, were found both above and below the level of the footsteps. In the Cheirotherium of Storeton, both the hind and the fore feet have each five toes, the size of the hind foot is about five times as big as the fore foot. In the American fossil, the posterior footprint is not even twice as large as the anterior, and the number of toes is unequal, being five in the hinder, and four in the anterior foot. In this, as in the European cheirotherium, one toe stands out like a thumb. The American cheirotherium was evidently a broader animal and belonged to a distinct genus from that of the Triassic age of Europe. Its habit would be, I should suppose, from its footsteps being more equal in size, to go more on all fours than its European brother.

Professor Boyd Dawkins, as the members of this Association will perhaps remember in our recent visit to Owen's College,* while describing some footprints to us, noted the fact that, as human beings in pairs are not unusual sights to be seen walking together, in Lancashire to-day, so pairs of cheirotherian footprints are found indelibly imprinted in the sandstone of our district, showing that these animals took their walks together on the margin of the lake, perhaps under triassac moonlight.

Only under specially favorable circumstances can it have happened that these footprints would have been *well* preserved, while *millions* of them would be made and obliterated, and are

* 1st October, 1881.

even now being constantantly made and obliterated. Travelling some years sgo in New South Wales, it happened to be my fortune to come across such conditions as appear to me to be well suited to their production and preservation, and I think in describing briefly those conditions, we may perhaps realize what has happened "many a time, and oft," in the history of our world, and probably in our own neighbourhood.

Lake George in New South Wales, is a salt lake, about thirty miles long. Nearly twenty years ago, full of life and hope, I camped on its banks, and on the side by which I passed, it had a very wide margin of mud, and for a considerable distance from the shore its waters were very shallow, as shown by the aquatic plants growing and birds wading. During the drought of summer the waters of the lake retreat; during the wet season, they advance. *Innummerable* quantities of birds of *many* species were observed on its banks, footprints made immediately before the advent of the wet season, at or near the margin of the water, with hot weather to harden the mud, and perhaps, produce sun cracks by shrinkage, and no rain in the immediate neighbourhood to wash off the fine edge of the impression, then suppose the lake to be flooded by a river flowing into it, the mud-charged waters rapidly advance, and deposit their sediment in the impressions, completely filling them up, preserving them as if only made yesterday, *for all time*, when instead of mud, they shall have been turned to stone.

So we see that footprints have engaged the attention of the philosopher and geologist, and afforded ample material for thought and speculation, aud I will close my remarks by showing that they have served a well known modern poet, to point his moral, and adorn his tale.

"Lives of great men all remind us,
We may make our lives sublime,
And departing, leave behind us,
Footprints on the sands of time,
Footprints which perhaps another,
Sailing o'er life's stormy main,
Some forlorn and shipwrecked brother,
Seeing may take heart again."

LONGFELLOW.

LIVERPOOL GEOLOGICAL ASSOCIATION.

9th January, 1882.

At the Ordinary Meeting, held this date, at the Free Library, Mr. Henry Bramall, M. Inst. C.E., President, in the Chair, the following gentlemen, proposed on 5th December, were elected as members :—

Messrs. Henry Young, R. L. Tapscott and Alex. Brodie.

Proposed as members :—Messrs. Hopkin Thomas, 4, Cable Street; T. H. Williams, 2, Chapel Walks; John A. Tate. The College of Chemistry, 96, Duke Street; William Houlding, 34, Tynemouth Street; Bruce M. Broadfoot, Solicitor, 67, Huskisson Street; Frederick Marrow, 20, Boundary Street, Liverpool; C. H. Morgan, 72, Bank Road, Bootle; William Hills, Fountain Street, Higher Tranmere; W. H. Roughsedge, St. Helens.

DONATION.

"Geological Papers, 1874 to 1881," by T. Mellard Reade, C.E., F.G.S., F.R.I.B.A., presented by the Author.

Abstract of a Paper read :—

"CHEMICAL ACTION IN RELATION TO GEOLOGICAL CHANGE."

By A. Norman Tate, F.I.C.

Having alluded to the action of water and ice on the earth's surface, and illustrated his remarks by several lantern views of mountain streams, waterfalls, rivers, glaciers, &c., the author proceeded to speak of the chemical action of substances held in solution in water. Being capable of exerting great solvent action, water is never found pure in nature, and the substances that it gathers up greatly assist its physical and mechanical action, by reason of the chemical changes they bring about. Carbonic Acid (carbon dioxide) is one of these. By its action on carbonates of lime, magnesia and other bases it exerts great power of disintegration, especially in districts

where calcareous strata exist. Small crevices and fissures, in which water alone can exert but little action, are, by the solvent power of carbonic acid, rapidly widened, and larger passages worked out; consequently such rocks as those of the limestone formation become more readily disintegrated than others which are of a more siliceous character. One result of such actlon is an easier passage of rain and surface water into limestone rocks, and the production of underground streams, which oftentimes are of very considerable volume and length. The stream which issues from one end of the Cheddar Pass, in Somersetshire, and another that flows from a cave called Wookey Hole, near Wells, have both been proved to be supplied with water that disappears many miles away on the Mendips. Both these streams hold a considerable amount of carbonates of lime and magnesia in solution, and the amount dissolved away from the strata through which they pass, represents a removal of these carbonates to a great extent each year. Many similar streams are to be found in other limestone districts, such as those of Flintshire and Derbyshire, and the stream issuing from the Peak Cavern, which probably may be traced through the Speedwell and Blue John mines, near Castleton, is another example of an underground river removing large amounts of earthy carbonates by the action of the carbonic acid held in solution in water. But these carbonates are often deposited as carbonic acid escapes, and the well known stalactites and stalagmites are familiar examples of such action, as also are the beds of travertine and tufa, such as the tufa beds at Matlock Baths, showing that carbonic acid is not only capable of breaking down rock formations, but of building them up also. Another result of the solution of carbonates is their removal into rivers, lakes and oceans, there to afford to animal organisms, the lime, &c., which they build into their coverings and skeletons, which, when they die, they leave as calcareous accumulations.

Other substances act with carbonic acid when dissolved *in water. Decaying* vegetable matters yield to water two kinds

of soluble substances, organic and inorganic. By the decay of the tissues of plants, salts of potassium, calcium, and magnesium, together with silica and phosphates are set free. These, dissolved and carried by water, are capable of producing many chemical changes. Much of the organic matter passes into streams and rivers, and its presence is shown by the brownish coloration of these waters. One action of such organic matter is to absorb oxygen, and, as one result, more carbonic acid is produced, and nitrates and nitrites are also reduced to ammonia. It is interesting to note what takes place in the filtration of such water through different strata. Take for example percolation of water through an ordinary clay soil, it loses ammonia, potash, silica, phosphoric acid and organic matter. Thus these substances, specially serviceable for plant growth, and derived from decaying vegetable organisms, become again locked in the soil ready to afford further food for vegetation. Substances such as chlorides, sulphates and carbonates of soda, lime and magnesia pass on with the water. There can be no doubt that during this percolation of water through permeable strata, interesting chemical changes take place. For example, the hydrated double aluminous silicates play an important part in a process of double exchange, giving up an equivalent of lime and soda for the potash and ammonia that is retained. These actions deserve further investigation, and a further action of carbonic acid and organic matter combined may be referred to as bearing upon the formation of metalliferous deposits. Iron is very widely dispersed throughout different strata, in the form of oxides. Two of these, the protoxide and peroxide, are very largely met with. The protoxide is soluble in water containing carbonic acid, but the peroxide is not soluble.

The organic matter present in the water takes from the peroxide of iron a portion of its oxygen, carbonic acid being produced at the same time; the oxide being soluble in water charged with carbonic acid and other acids, weak organic acids present also in the water, is dissolved and carried away. The solution if again exposed to the air

absorbs oxygen, and peroxide is again formed; such actions as these are capable of explaining the formation of beds of iron ore, and are worth noting in connection with the existence of large deposits of iron ore in the neighbourhood of coal, which undoubtedly is of vegetable origin, and the frequent occurrence in the same localities of clay beds containing but very little iron. Oftentimes again, although coal may not be present, carbonaceous substances, such as graphite, exist near deposits of iron ore such as those of Cumberland. The action of organic matter upon sulphates and the consequent formation of sulphuretted hydrogen and sulphides would appear to have played great part in the formation of other metalliferous deposits. Similar action on manganic oxide would occur as with peroxide of iron. Another form of iron ore, iron pyrites, is often found under circumstances suggesting the action of organic matter in its formation, and the same may be said of other metallic sulphides. One example may be mentioned of a trunk of a tree taken from the mud of a spring in Ontario, in which the undecayed wood was deeply incrusted with iron pyrites. The action of dead organic matter seems naturally to suggest the consideration of actions exerted by living organisms, and by these we find much chemical work done in gathering up and concentrating mineral matters. Reference has already been made to the action of marine animals in gathering up carbonate of lime and as an example of plant action the work of marine plants in taking up iodine may be referred to. Sea water has been shown to contain iodine in the form of iodate of calcium to the extent of only 1 part of the iodate in 250,000 of water, but the ashes of sea weeds yield iodine in a proportion sufficient to allow them to be profitably used for the extraction of iodine for commercial purposes. The collection and consequent concentration of potash by vegetable life may also be referred to.

Returning to carbonic acid, allusion was made to its influence in the decomposition of felspathic rocks, and the formation of clay beds, &c., also to its action as a carrier of bases in solution in water, which by interchange with other dissolved salts, brought about chemical actions that deserved consideration in studying the formation of dolomites, &c. Reference was also made to chemical changes, consequent upon the presence of water under conditions of high temperature and pressure, and the bearing of these upon that theory of volcanic action, which supposes a condition of igneous-aquefous fusion of sedimentary strata under the influence of elevated temperature and great pressure.

LIVERPOOL GEOLOGICAL ASSOCIATION,

6th February, 1882.

At the Ordinary Meeting, held this date, at the Free Library, Mr. HENRY BRAMALL, M. Inst., C.E., President, in the Chair, the following gentlemen, proposed on 9th January, were elected as Members:—

Messrs. Hopkin Thomas, T. H. Williams, John A. Tate, W. Houlding, C. H. Morgan, William Hills, W. R. Roughsedge, Bruce M. Broadfoot, and Frederick Marrow.

Proposed as Members:—

Messrs. James Plastow, 169, Great Homer Street; Samuel Duff, 55, St. Martin's Cottages, Ashfield Street; Arthur J. Dunsford, Wynch House, Seacombe; P. B. Deuchar, 17, Kingsley Road, Liverpool.

DONATIONS.

Index to first 25 vols. of "Transactions," from the North of England Institute of Mining and Mechanical Engineers, Newcastle-on-Tyne. Reports Nos. 9 and 10, (1879-80; 1880-81.) and "Proceedings," Nos. 1 and 2, (1874; 1878.) from the Chester Society of Natural Science. "Rules, &c.," of the Liverpool Science Students Association, from the Association. "On the varieties of the Shells belonging to the genus *Nassa*," and other papers, by Frederick P. Marrat, presented by the Author.

The following Paper was read:—

"RIVERS."

By T. MELLARD READE, C.E., F.G.S. F.R.I.B.A

The selection of the subject of the paper I have been asked to give to you to-night, with a geological audience such as I am addressing, demands little or no explanation. To those who have paid much attention to physical geology, the profound significance of the silent action of the RIVER, not alone in modifying the surface features of the land, but in the actual construction of the crust of the earth, scarcely needs emphasising. Yet I venture to think that the surface action,

which is visible to us, has been dwelt upon rather to the exclusion of the re-constructive action of the RIVER, and this latter's relation to the sphere we live on, I hope partially, if inadequately to develop.

To begin at the beginning, we may ask ourselves, what is a RIVER? An application to our good friend the dictionary will tell us that the word is directly derived from the French *riviere*, a river, or in old French, a bank, shore, or country on the banks of a river. Its real origin no doubt being the Latin word *ripa* a bank or shore. We thus see even in the early stages of civilization the relations of the water of the river to the valley in which it runs was recognized, though it has been left to us moderns to incontestably prove that the valley itself is the work of the running water.

The absolute necessity of the river to mankind and to the supply of their wants, as well as the instinctive recognition of it as a grand natural feature, has, from the earliest ages, invested it with the deepest poetical sentiments and associations and even often with a sacred character; as was the Nile, the Jordan, the Tiber, and as is still the Ganges.

Our poets are full of allusions to rivers. Goldsmith speaks of the "murmuring Loire," Tennyson, of the "brimming river," and Thomas Aird in a beautiful little poem, thus apostrophises the river :—

> "Infant of the weeping hills,
> Nursling of the springs and rills."

Beattie in his "Minstrel," gives this fine picture of river-action—

> "And hark! the river, bursting every mound,
> Down the vale thunders, and with wasteful sway,
> Uproots the grove, and rolls the shattered rocks away."

Thomson's Seasons are full of beautiful descriptions of river scenery, and rivers in their varying moods. Speaking of the Nile, he says in "Summer,"

> "Rich king of floods! o'erflows the swelling Nile."

And after tracing his origin

> "*From* his two springs in Gojam's sunny realm,"

continues

> "He sports away
> His playful youth, amid the fragrant isles
> That with unfading verdure smile around.
> Ambitious, thence the manly river breaks;
> And gathering many a flood, and copious fed
> With all the mellowed treasures of the sky,
> Winds in progressive majesty along;
> Through splendid kingdoms now devolves his maze;
> Now wanders wild o'er solitary tracts
> Of life-deserted sand; till, glad to quit
> The joyless desert, down the Nubian rocks
> From thundering steep to steep, he pours his urn
> And Egypt joys beneath the spreading wave."

And in "Winter" is a description of a river, remarkable as containing what is now a recognized geological truth, or feature peculiar to river valleys, the final gorge through which most rivers cut their way to the sea.

> "Wide o'er the brim, with many a torrent swelled,
> And the mixed ruin of it's banks o'erspread,
> At last the roused-up river pours along;
> Resistless, roaring, dreadful, down it comes,
> From the rude mountain, and the mossy wild,
> Tumbling through rocks abrupt, and sounding far;
> Then o'er the sanded valley floating spreads,
> Calm, sluggish, silent*; till again, constrained*
> *Between two meeting hills*, it bursts away,
> Where rocks and woods o'erhang the turbid stream;
> There, gathering triple force, rapid and deep,
> It boils, and wheels, and foams, and thunders through."

A more exact description of a river it would be difficult to find, even in a geological work; such is the prophetic insight of the poet, when seizing the salient features of nature.

But however refreshing to a scientific mind to take a dip into the poets, or, to make a joke, their rivers, we must come at last to the more literal, leaving the impressional behind.

Looked at purely from a physical point of view, a RIVER is a main drain for part of an island, or a continent. A channel that has been made by the ceaseless rushing of water

for untold ages, a silent highway by which water taken up by evaporation in the atmosphere from the great oceans, condensed in the form of rain, returns again to the sea in a collected form, along a line of least resistance. To those who are not familiar with the science of hydrography it is difficult to realize the mighty effect of the fall of a small quantity of rain, if spread over a large area. Engineers have a ready way of calculating it, for one inch of rain spread evenly over an acre weighs as nearly as possible one hundred tons. This fact of itself is sufficient to show what mighty mechanical work a river can do. A fall of one inch of rain a day is not an unfrequent occurrence, even in this neighbourhood. There were in 1880 *six* such falls, and on one occasion in July, 1877 I registered 2¼ inches in twenty-four hours. In thunderstorms an inch may fall in an hour, but these falls are mostly local, and restricted. It is on the occasions of heavy continuous falls that havoc is done, such as Thomson has so well described. If the rainfall were spread evenly over the whole of the year, the rivers would easily and silently carry off all the water that falls upon the land, but their valleys would shew characteristics they do not generally possess.

But a consideration of the enormous quantity of water which collects in a large river from its basin will aid us in understanding the extraordinary effects of what is called subaërial denudation—a subject that requires an education to appreciate.

We who live by the sea are familiar enough with the mighty action of the wind wave, because its force is concentrated and its action can be seen and measured, but the silent work of rain requires *reason* and *investigation* before it is appreciated. The effects of the river in flood are more nearly related to those of the sea in a storm. They both act principally mechanically, and both tear up deposits they have laid down in their quieter moods, as well as grind down hardened rocks deposited under different conditions ages ago.

But as the ocean is the feeder of the river with water *through evaporation* and condensation the river repays the

debt by bringing within the ocean's mighty arms the wrecks of the land; returns to him the materials of the rocks, which for a time the elevatory forces of heat within the earth have robbed from his realm Thus is the constant circulation kept up, the life, the death, and the renewal which has been uninterruptedly going on from the earliest dawn of geologic time, and which is still, so far as we can measure and infer, as active as ever.

Those who have not considered the subject, and even some geologists still have a difficulty in understanding how the present rivers could have cut out the valleys in which they run. Hence the invention of such things as Mr. Tylor's "Pluvial" period during which time he credits the rivers with a supply of water nine times and a power of denudation 729 times as great as that of the present*. There is no doubt that every river basin must have had its fluctuations of rainfall within certain limits; but there is no reason to suppose that on the whole there was more or less rain in previous periods than now; at all events the onus of proof lies on those who assert that there was. But such is the constitution of the human mind that it often fails to recognise the tremendous effects of small recurrent causes.

I will try to explain in as simple language as I can command the mode in which the great majority of geologists recognise that the rain and rivers have worn away the land.

That the question may be considered in its simplest form I will select as an example a country where the rocks that have been eroded have preserved a tolerably horizontal arrangement, and we could hardly have a better one than the Peninsula of India. In the manual of the Geology of India by Medlicot and Blanford, they say, "The peculiarity of all the main dividing ranges of India is, that they are merely plateaus, or portions of plateaus that have escaped denudation. There is not throughout the length and breadth of the Peninsula, with the possible exception of the Arvali, a single great range of mountains that coincides with a definite axis of

* *Geological* Magazine, November, 1881, page 525.

elevation, not one, with the exception quoted, is along an anticlinal or synclinal ridge. Peninsula India is in fact a table-land worn away by subaërial denudation, and perhaps to a minor extent on its margin by the sea, and the mountain chains are merely the dividing lines left undenuded between different drainage areas. The Sahyádri range, the most important of all, consists to the northward of *horizontal, or nearly horizontal* strata of basalt, and similar rocks, cut into a steep scarp on the western side by denudation, and similarly eroded, though less abruptly to the eastward. The highest summits, such as Mahábleshwar, (4,540 feet), are perfectly flat-topped, and are clearly undenuded remnants of a great elevated plain. South of about 16° north latitude, the horizontal igneous rocks disappear, and the range is composed of ancient metamorphic strata; and here there is in some places a distinct connection between the strike of the foliation and the direction of the hills; but still the connection is only local; and the dividing range consists either of the western scarp of the Mysore plateau, or of isolated hill groups, owing their form apparently to denudation. Where the rocks are so ancient, as those are that form all the southern portion of the Sahyádri, it is almost impossible to say how far the original direction of the range is due to axes of disturbance, but the fact that all the principal elevations, such as the Nilgiris, Palnés, &c., some peaks on which rise to over 8000 feet, are plateaus and not ridges, tends to show that denudation has played the principal share in determining their contours."* From this description we would infer that these plateau rocks, consisting of three great groups, viz. the Vindhyans, Gondwánas and the Deccan traps, the latter supposed to be of cretaceous age, must have been exposed to the wearing action of atmospheric causes for untold ages; and in fact we are informed by the same high authority "there is evidence of a singular permanency of conditions, and freedom from severe disturbance at all periods after early palœozoic times." It is thus seen that we here are not troubled with the peculiar complications in

* *Manual of the Geology of India*, introduction, page v.

the history of the river systems, which Ramsay has done so much to unravel in this country and Europe.

As the Peninsula of India gradually rose out of the Palæozoic Sea the rainfall would establish for itself certain lines of drainage. There is every evidence to prove that the upheaval of a continent is an extremely slow process and if this be so, the initiatory stages of the river system would begin on islands. The tilt of the strata however small would suffice to determine the direction of the flow, the atmosphere would find out the softest rocks, and as disintegration took place through chemical action the mechanical action of rain-wash would clear away the smaller particles. Two great causes would therefore operate; the slopes or gradients, and the nature or texture of the rocks. As the land rose out of the sea these lines would be, so long as it was free from great disturbances or lava flows, unalterably determined. Once the drainage lines have become traced on the continent the rest will follow with certainty, the rivers will deepen their beds, the atmosphere and rainwash will widen the valleys, the same will follow with the branches, and these eventually widening and coalescing, the river basin will be formed. The deepening will go on until the grade to the sea is lowered to the non-erosion point, when changed conditions may make portions of the river valleys areas of alluvial deposit That this has taken place over and over again in every part of the globe is incontestably proved, but it is only seen by the *eye of reflection;* the process is so slow. The mode in which the excavation takes place will vary according to the character of the country and the slope. Near the mountains where deep and steep gorges are cut, the sides of the streams are undermined and boulders formed and hurried along. These may be ground to powder by mechanical attrition before they reach the sea, or they may be laid down as riverine conglomerates, such as the Sivalik conglomerates* in the extra Peninsular area of India, or in the old river-beds of California, afterwards capped by

* *Manual of the Geology of India*, vol ii. p. 525.

lava flows, as described by Mr. Joseph Le Conte*. But it is not in this way that the largest amount of denudation takes place, that is silent, unseen, due to the disintegration of the rock by chemical causes, which eventually produces particles fine enough to be carried away mechanically by rain-wash. If we could only notice it we should find every particle of superficial earth or soil on the travel. The process is slow, but if it were not slow no soil would be left for vegetation to luxuriate in. It by no means follows that the rate of disintegration of rocks is directly proportional to the rainfall; slow percolation moisture, alternate wet and dry conditions, alternations of heat and cold, will be more efficacious than deluges of rain, though the nature of the conditions for most rapid disintegration differs with the nature of the rock itself. The mechanical effects of floods seems to be that of the removal at intervals of the accumulated effects of atmospheric corrosion. If I may be allowed the simile, the disintegrating chemical action of the atmosphere is the navvy's pick that loosens the material, the rainwash is the shovel by which it is thrown into the cart, wagon, or barge, represented by the river, the valley is the highway by which it travels to the sea, to be finally tipped on the tipping bank, the delta, or washed by currents far out into the open ocean. But lately Mr. Darwin has shewn in his work on "Mould and Earthworms" that there is another excavator at work almost equally ubiquitous, that on every acre of ground, when the conditions are favourable, throws up ten tons of earth per annum. Digging deep down into the superficial soil this busy little animal throws up on the surface in agglutinated wormcasts all the particles small enough to pass through its body. Thus is not only introduced a soil-sifter but Mr. Darwin points out that by repeated passages through the body of the animal the material must be ground together as in a little mill. It is evident that if the estimate of ten tons to the acre be a true one, the superficial soil must again and again pass through the bodies of worms, for it is equal to *6400 tons per* square mile per annum, or over ten times the

* *American* Journal of Science, 1880. p. 176, vol xix.

most liberal estimate of the mean denudation of the land.* To Mr. Darwin is due the discovery of this new geological agent. Although man has had worm casts before his eyes from the beginning he never realized that it meant anything important,but geni us and calculation show that it does.

We may say of the earthworm

No human being is so fine,
Or skilful at the sap and mine,
The little creature makes no bones,
To dig and drop the greatest stones,
Without the aid of "Jack" or pushing,
Or fear of a dreadful crushing.—
No greater digger was since Adam,
He digs and burrows through Macadam,
And even heaps his little pile
Upon the Roman pavement tile,
And in old buildings maketh merry,
Or even ruined cities bury,
Preserving them for Antiquary,
From this 'tis true the earth is blessed in
Passing through the worm's intestine,
And fields and flowers shew the plan
The worm is nature's husbandman.

But the river does not only carry "dirt" it sweeps away an enormous amount of matter in solution, principally in the form of carbonates and sulphates of lime, a quantity I have estimated for England and Wales, at a mean of 143½ tons per square mile annually.† This matter is swept out to sea, diffused through the great oceans and there appropriated by foraminifera, corals, pelagic molluscs calcareous sponges &c., for the formation of their tests, or skeletons as the case may be.—The matter in suspension on the other hand is principally deposited nearer home, partly on the river-flats in the form of alluvium to be again dug into and swept away, when the river in flood changes its meandering course, cuts

* See "Chemical denudation in relation to Geological Time," Mellard Reade—page 29, where it is estimated at 600 tons per square mile *annually.*

† "*Chemical* denudation in relation to Geological Time," page 20.

straight across a loop and hurries everything pell mell before it. To take an illustration from near home, the contractor for the laying of the sewerage pipes from Wigan to the farm below Newborough informed me that he cut through some of the old beds of the river Douglas no less than a dozen times, in a space of 14 miles. But by far the larger part of the "dirt" is carried forward to the point where the river debouches into the sea, or it may be a lake, and is there deposited. These deltas, as they are called, may be well seen in some of the Swiss lakes, or to come nearer home, in our own lake district, but the most remarkable examples are those mentioned in the first report of the newly organised American Geological Survey, as occurring in the now dried up basin of Lake Bonneville, at various levels, making striking features in the topography of the district. This ancient lake of which the Great Salt Lake is but a sorry and alkaline remnant, was as large as lake Huron, but its peculiarity is that the drying up has been so geologically recent, that the deltas of the rivers entering it have been left at various levels around its margin. They might not inaptly be described as "terraced deltas," Mr. Gilbert says.* The Great Salt Lake Desert and congeries of valleys connected with it, were filled with water at a period so recent that the vestiges of the flood are little impaired at the present time. The sea cliffs that were carved by the dash of the ancient waves are sea cliffs still, though they stand a thousand feet above the present level of the Great Salt Lake."

Let us now direct our attention to several continental rivers. The Danube and the Rhine in Europe; the Nile and the Congo in Africa, the Ganges and the Yang-tse Kiang in Asia, the Mississippi and Colorado in North America, and the Amazons and La Plata in South America, may be cited as typical examples. Of these the fullest and most accurate records relate to the Nile, the Danube and the Mississippi. The Nile, which from the earliest ages of Egypt had been an *object of solicitude* to the multitudes living on its banks, has

* *First report* of U.S. Geological Survey—page 24.

lately from the scientific investigations of Mr. Fowler, the engineer to the Khidive, yielded us some very accurate knowledge. He finds that in 1873 the minimum measured flow was 355 cubic metres per second, Linant Bey states that the volume of water passing down the river at Cairo from measurements during three "high Niles" was 8166, 9460, and 9740 cubic metres per second,* thus it is seen that the flow of the high Nile is some 26 times that of the low Nile. The suspended matters in Nile water according to the late Dr. Letheby† varied from 4.772 parts per 100,000, in May 1875, to 149.157 in August 1874. A consideration of these simple facts gives us an accurate insight into the denuding and transporting power of a river, showing that it varies most enormously, delivering in the particular case of the Nile 850 times as much matter in suspension during flood, as during extreme dry weather flow. Neither the amount nor the proportion of solid matter dissolved in the water is, as I have often pointed out before, subject to such great fluctuations.‡ In the case of the Nile it ranged from 13.614 to 20.471 per 100,000 parts in 1874, or in other words the Nile in flood brings down 41 times more matter in solution than it does during low Nile. This is a very important fact having a considerable bearing upon questions of physical geology, and has not hitherto been properly considered, but I hope in the end by continued iteration, and presenting the fact in various forms, to insense Geologists into its importance at last!

It will take too much time and become wearisome to develop this part of the subject to any great extent, but it will be instructive to compare these figures with those of the Danube. The extreme low water flow of this river is given by Sir C. A. Hartley at 70,000 cubic feet per second, or 1,982 cubic metres, and an extraordinary flood 1,000,000 cubic feet per second, or 28,316 cubic metres, the flood being thus over 14 times the dry-weather flow. The smallest delivery of suspended matter per day of 24 hours is stated at 11,000

* "The Barrage of the Nile."—Engineering, March 17, 1876.
† "*Egyptian Irrigation second Report*," page 28—J. Fowler.
‡ *Chemical Denudation in relation to Geological Time*"

tons, the greatest, 2,500,000 tons; or a variation of 227 times. Great as this variation is, it is seen that the river in this respect does not reach the extremes of the Nile.

The next thing I must touch upon is the *age* of rivers. If the principles I have feebly attempted to lay down are correct it follows as a consequence that most continental rivers of any pretensions are of great antiquity; ancient they are, even as measured by geological time. Professor Ramsay,* who of all geologists has paid most attention to this subject, considers that the valley of the Severn is of immediate post-Miocene date and is one of the oldest in the lowlands of England; he is also of opinion that the Rhine, as it now exists is post-Miocene. In a paper on the Physical History of the valley of the Rhine,† he says; "but this seems certain that, after the post-Miocene upheaval of the Alps, the present main drainage of the area began before the glacial episode and was in many important respects only established by the influence of glaciers." To quote a still more recent writer, Captain Dutton in his admirable report on the Geology of the high plateaus of Utah, which may be termed a monumental monograph on erosion; speaking of the River Colorado he says impressively: "now the grand truth which meets us everywhere in the plateau country, which stands out conspicuous and self evident, which is so utterly unmistakable, even by the merest tyro in geology, is this: *the river is older than the structural features of the country.* Since it began to run, mountains and plateaus have risen across its track and those of its tributaries; and the present summits mark less than half the total uplifts. The streams have cleft them to their foundations. Nothing can be clearer than the fact that the structural deformations unless older than Tertiary time, never determined the present courses of the drainage. The rivers are where they are, in spite of faults, flexures and swells, in spite of mountains and plateaus."‡

* Physical Geography of Great Britain, fifth edition.—page 510.

† *Qaarterly Journal* of Geological Society, 1874, page 85.

‡ *Geology of the* High Plateaus of Utah.—page 16, 17.

If these are correct inferences, certain consequences follow which seem to have been strangely lost sight of by geologists. Great efforts have been made to estimate the age of deltas. Lyell was the first to attempt it, and all honour to him for his intrepidity. The delta of the Mississippi, Lyell calculated, must have taken 67,000 years to accumulate, but the more accurate survey of the river, by Messrs Humphreys and Abbot, reduced the estimate to 33,500 years, but in the tenth addition of his "Principles" (1867), Lyell very fairly observes—"On the whole I am not disposed to regard the estimate which I made in 1846 of the time required for the accumulation of the delta, as extravagant. The rate at which the river accomplishes a given amount of work is no doubt nearly double what I supposed, as shown by Messrs. Humphreys and Abbot; but on the other hand the quantity of work done, or of mud and sand which has been carried down into the gulf, is far greater than that which I assumed as the basis of my calculation."* Of the justice of these remarks, I have not the slightest doubt. I think that further enquiry would tend to increase the estimate, for no one can say that the crust of the earth is mainly composed of deltaic deposits, so that if the larger part of the denudation of the land going to make up future rocks is subaërial and therefore must have travelled to the sea by rivers, it follows as a consequence that the larger part is by some means or other distributed by the sea, as marine deposit, and therefore this marine portion must be abstracted from the deltaic accumulation, if our estimate is to be correct. Saving the question of the variation of rainfall, in the river-basin this mode of calculation will only give us the absolute minimum age. I am of opinion, also, notwithstanding the "Challenger" experiences, for in her cruise she avoided seas opposite the mouths of great rivers, that mechanical deposits are more widely spread than is generally thought. Some rivers such as the Parana in South America bring down matter so finely divided, that months of repose will

* Principles of Geology, Tenth Edition, volume 1, page 462.

not render the water clear.* Is it to be supposed that such water getting into ocean currents will not be distributed far and wide?

One of the peculiarities of the great continental rivers, which I have never seen satisfactorily accounted for, is that the beds are usually far below the present surfaces of the deltas. I could not say it is never otherwise, but in all cases that I know of, where borings have been made, many hundred feet of deltaic deposits have been pierced before the bed-rock was reached. That is a geological nut to crack. But this is not the time or place to crack it. Oscillations of level have taken place, no doubt evidences of them are to be found everywhere, but why should the Ganges and the Mississippi apparently be both at the lowest swing of the pendulum?

My sketch of rivers and river action is but an imperfect one. The examples I have given have been chosen from those most accurately ascertained, but they are small ones. The River Plate according to observations of Mr. Bateman. the the eminent hydraulic engineer, delivers in dry weather 670,000 cubic feet per second, "a quantity equal to the mean volume of 33 years passing down the Mississippi." Dr. Behm estimated the mean delivery of the Congo at 1,800,000 cubic feet per second, Burton at 2,500,000 cubic feet, but these estimates are mere rough approximations. The Yang-tse at Hankow is estimated at 650,000 cubic feet per second,† while the mighty Amazons rolls to the Atlantic a mean flood of from 2,700,000 to 3,510,000 cubic feet per second. Thus that "father of waters," the Nile, sacred from its historical and scriptural associations, is now, whatever it may have been in earlier geologic time, but a pigmy as compared to a giant, when we think of the Colossus of the American continent, the relations of the flow being, assuming the determinations to be correct, as 1 to 33, that is, the Amazons has 33 times the volume of the Nile.

* George Higgin, Proceedings of Institution of Cival Engineers, vol. 57. *page 272—293.*

† *Nature, September* 23rd, 1880, pages 486-7.

I have not exhausted my subject, but I may have trespassed on your patience, though I trust I have made plain some of the functions of rivers in the geological economy of nature. It is wonderful to reflect that these enormous water powers which modern enterprise with scientific audacity proposes to utilize as motors, hundreds of miles from their source by means of the ubiquitous electric circuit are all due to the condensation of invisible vapour drawn up by that father of life, our sun. In the words of Thomson, I may fitly conclude :—

"Those rolling mists, that constant now begin
To smoke along the hilly country, these,
With weighty rains and melted Alpine snows
The mountain cisterns fill,—those ample stores,
Of water, scooped among the hollow rocks,
Whence gush the streams, the ceaseless fountains play,
And their unfailing wealth the rivers draw."

LIVERPOOL GEOLOGICAL ASSOCIATION,

6th March, 1882.

At the Ordinary Meeting, held this date, at the Free Library, Mr. Henry Bramall, M. Inst. C.E., President, in the Chair, the following gentlemen, proposed on 6th February, were elected as Members :—

Messrs. James Plastow, Samuel Duff, A. J. Dunsford, and P. B. Deuchar.

VICE-PRESIDENCY.

The President announced that owing to the resignation of Mr. Thos. Shilston, M.I.N.A., in consequence of his leaving the district, the Council, in accordance with Law III, had elected Mr. Charles E. Miles, as Vice-President, and had further elected Mr. John Morris as Member of the Council to fill the vacancies.

DONATIONS.

Annual Reports, Nos. 1, 2, and 3, of the Chester Free Public Library: "Geoffrey Chaucer," by Henry Houlding, and "The Philosophy of Recreation," by J. E. Brumwell, M.D., presented by the Burnley Literary and Scientific Club.

The following Papers were read :—

"IRON PYRITES."

By H. T. Mannington.

The science of Mineralogy being most intimately associated with that of Geology, and becoming so more and more, as is evidenced by the great attention now paid to the chemical and mineralogical constitution of rocks, I feel that no apology is required for asking your attention for a short time to some points in connection with a mineral of the widest diffusion and one which is met with by the geologist in almost all, if not in every formation.

That mineral is Iron Pyrites, no doubt known to all, to a

greater or less extent; a mineral about which more might be said than I can hope to say in the time at my disposal.

I may conveniently divide my subject into two parts; considering, first, the chemical and physical characters of the mineral, and secondly, its mode of occurrence, also making a slight reference to its commercial importance.

Before proceeding further, however, it may be advisable to mention something of the Iron sulphides in general, which are numerous, consisting of Iron and Sulphur in varying proportions. The proto-sulphide (FeS) is rare, but appears to occur sometimes, mixed with other sulphides of Iron.

The bi-sulphide (FeS^2)—Iron Pyrites or Mundic—the "Fer sulfuré" of the French, the "Schwefelkies" of the Germans, is found abundantly in nature, and is, with the exception of the oxides, the most abundant of the Iron minerals; it rarely consists of pure FeS_2, but is almost invariably mixed with other ores—usually sulphuretted—or with gangue; a great variety of the metals occur associated with it in this way, although frequently in very small quantity. Iron Pyrites, when pure, contains 46.6 °/o Iron, and 53.3 °/o Sulphur. It may be produced artificially (among other methods) by passing dry sulphuretted hydrogen over crystals of ferric oxide heated to a considerable temperature, which fact may sometimes account for the pseudomorphs of Iron Pyrites after ferric oxide, which are found, and perhaps also for some of the deposits of the mineral.

The mineral Marcasite is of the same composition as Pyrites, viz. FeS , but of a different crystalline form; they frequently occur associated together. The sesqui-sulphide (Fe_2S_3) occurs largely in nature, but always in combination with Copper sulphide, forming Copper pyrites ($Cu_2SFe_2S_3$) and Bornite or Erubescite ($3Cu^2S,Fe^2S_3$).

Mispickel is a double sulphide of Iron and Arsenic, its formula being FeS_2+FeAs_2. There is also the mineral Lonchidite, which appears to be a mixture of Marcasite and Mispickel, it occurs in some gold districts and is worked for that metal.

Finally, we have Pyrhotine or Pyrhotite, Magnetic Pyrites, of which the formula is Fe_7S_8 and which may be considered either as a mixture of proto and bi-sulphide of Iron or as proto and sesqui-sulphide; both that prepared artificially and also the native mineral give sulphuretted hydrogen on treatment with hydrochloric acid. A mineral, "Krœberite," is mentioned by Dana, it is apparently a sub-sulphide of Iron, and is strongly magnetic.

To refer now more particularly to the three minerals, Pyrites, Marcasite, and Pyrhotine. The chief distinction between Pyrites (i.e. Iron pyrites) and Marcasite is the fact of their crystallizing in distinct systems although of the same composition, in other words, they are di-morphous,—Iron pyrites belonging to the Cubic system, Marcasite to the Rhombic.

The physical characters are sufficiently distinct as a rule, to distinguish it from other minerals without resort to chemical tests. It is from one of these that the name is derived, viz. its hardness, which is from 6 to 6.5—between Felspar and Quartz. The word "pyrites" is generally stated to be derived from the Greek "pur," (fire) owing to the fact that sparks could be obtained by striking pieces of the mineral together or with steel. Pliny mentions several substances as included under the name, of which Dana gives four, one of which, described as a kind "resembling brass or copper," was probably our Iron pyrites, although then, as is very often the case now, Copper pyrites was frequently confounded with it. The simple test of hardness will usually serve to distinguish it at once from its softer relative, Iron pyrites resisting a knife, Copper pyrites yielding to it easily. In later times it is stated to have been used in wheel-lock fire-arms, the sparks produced igniting the gunpowder in the pan of the weapon. The Sp. Gr. as given by Dana, varies from 4.8 to 5.2; the Streak is greenish or brownish black; the Colour of crystals is metallic or splendent, with a fine lustre, but these are the aristocracy of the race, the commonalty, or amorphous varieties, e.g., those used upon the large scale, are usually of a greenish-grey or

greyish-yellow colour, of unattractive appearance, and with little cleavage ; such as is found in the mineral is Cubic or Octahedral. The fracture is conchoidal and uneven. The crystalline form to which it belongs, as stated earlier, is Cubic, and the mineral occurs very frequently in cubes, octrahedra, and in forms derived from both, such as the pentagonal dodecahedron, the rhombic dodecahedron, &c.; macles and twin crystals frequently occur. Pseudomorphs after pyrites are often found, such minerals as Limonite, Goethite, Hematite, Quartz, &c., occur as such, and also Graphite and clay. In cubic crystals the parallel hemihedry, or the tendency to develope alternate faces, is frequently clearly shewn by the striations at right angles to each other;—(specimens)—this curious marking is ascribed by Dana to " oscillatory combinations of cube and pyritohedron " (i.e. pentagonal dodecahedron); fine cubes occur in Cornwall, and pentagonal dodecahedra and other forms are abundant in Elba, crystals even 5 to 6 inches in diameter are sometimes found. Dana mentions a remarkable crystal from Piedmont, which was a large pyritohedron, with a small converse pyritohedron astride of each of the six cubic edges. Small, irregular crystals have been found in the Vesuvian lavas, and remarkable compound crystals occur in clay at Münden, and in chalk at Lewes (Sussex). (Various specimens were shewn, exhibiting foliation, aggregration, &c., and also pieces of pyrites with remarkable polish or " schlickenside," to be referred to later.) Before the blow-pipe on charcoal, pyrites gives off Sulphur, which burns, ultimately leaving a magnetic globule ; in a closed tube it gives a deposit of Sulphur ; it is insoluble in cold hydrochloric acid, but is decomposed by nitric acid.

As before stated the mineral is rarely, if ever, pure FeS^2, the metals Copper, Arsenic, Lead, Zinc, Antimony, Tin, Nickel, Cobalt, Maganese, Gold, Silver, Thallium, Tellurium Selenium, Indium, and possibly others, have been found. Gold is usually disseminated invisibly through the mass, the *pyrites* being occasionally worked for it. Auriferous pyrites *is frequently* found in gold regions, it being common at the

mines of Colorado and at many in California. Copper occurs frequently, replacing iron or existing as copper pyrites, and also Thallium which was discovered by Crookes in the dust of the flue leading from a pyrites kiln; the pyrites of the Rammelsberg mine, in Germany, is especially rich in it, and a curious case of its occurrence is that in the furnaces of the Bethlehem Iron Works, Pennsylvania, where it is attributed to the pyrites of the coal used (from the same State).* Arsenic is common, appearing frequently to occur associated with copper; in the ores of commerce it is usually found that if an ore be rich in copper it is also proportionately high in arsenic. Schnabel found 0.17 °/₀ Nickel in pyrites from Eckerhagen, and Dana describes a nickeliferous variety from Gouverneur, N.Y., which was similar in composition, pale bronze in colour and of radiate structure. He also mentions some specimens from Pennsylvania, which contained 2 °/₀ Cobalt, and shewed some crystal planes known in Cobaltite, but not before met with in pyrites; a cobaltiferous variety is found in Canada, at Brockville, and some other places.

Lead, in form of Galena, is of frequent occurrence, and silver also, in small quantity, probably associated with it, and in reference to this I may mention some experiments described by Meunier,† on the reduction of metallic solutions by sulphides, he mentions Galena, which reduces both silver and gold from solution, besides which he obtained precipitations with Iron pyrites, Copper pyrites, Blende, and Cinnabar. He thinks that this reducing action may sometimes account for the diffused presence of silver in Galena, it having precipitated it from solution, (*e.g.* from sea-water,) which is said to contain traces of that metal. (Specimen of pyrites shewn crusted over with metallic silver resulting from immersion for a few hours in nitrate of silver solution). A stanniferous variety (Ballasterosito) and containing tin and zinc, occurs in Galicia.

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* Dana. † Comptes Rendus, April, 1877.

Marcasite or Marchasite, (a name supposed to be of Spanish or Arabic origin)—the latter term being used by the older Mineralogists, and including the distinctly crystallized forms of Pyrites, (they using the term "pyrites" for the nodular and other varieties, and "wasserkies" for the less yellow and softer kinds, including also our "marcasite" and pryhotite,)—crystallizes in the rhombic system in prisms, frequently twinned, and occurs in fibrous, bulbous, &c. varieties, and also sometimes as stalactitic concretions, as "cock's-comb" pyrites, "spear" pyrites, &c., and as cellular pyrites, often formed by the decomposition of crystals of Galena, which contained films of pyrites between the layers. It is frequently called "wasserkies," which term may have arisen from the tendency of the mineral to become moist by absorption of water, (changing consequently to Sulphate of Iron,) or possibly from the term "weisserkies," which may have been applied to it on account of its light colour.

Pyrhotine—$Fe_7.\ S_8$ (probably seldom of just that composition), crystallizes in the Hexagonal system, although usually massive and amorphous, of granular structure, and metallic lustre. The colour is of a reddish-yellow, and streak of a dark greyish-black; the fine powder is attracted by the magnet.

Nickeliferous varieties are found with as much as 3 °/o Nickel, and traces of Cobalt. It occurs in Cornwall, Norway, parts of America, and other places; it is a frequent constituent of meteorites. and is found together with native Iron in the dolerite of Greenland, in masses varying from small grains to blocks of considerable size*

Turning now to a consideration of the modes of occurrence of these sulphides, (or rather of Pyrites and Marcasite only, for it will not be necessary to refer more specially to Pyrhotite,) we have here, what are probably familiar to most, the small cubes commonly occuring in slatey rocks, in fact although we find pyrites in rocks of all formations, it is in connection with

*Watts.

clay-slate and similar rocks, that the largest deposits appear to occur.

Not only does it occur in these symmetrical cubes, but also in other crystalline forms, and we frequently find it assuming the shape of long defunct animal or vegetable organisms, and formed in many cases, no doubt, by the action of decomposing organic matter upon solutions of Iron.

Such action has probably played an important part in the production of many metallic deposits, not only of Iron, but also of Copper and other metals.

It is unnecessary to enlarge further upon this point, as the subject was so lucidly put before the Association by Mr. Norman Tate at our last meeting, and it is, no doubt, fresh in the recollection of many present that he mentioned the case of a portion of tree-stem, crusted over with, and partially replaced by crystals of Iron Pyrites, (a similar specimen shewn.)

He (Mr. Tate), has most kindly furnished me with his original extract from the report of a lecture* before the American Institute of New York, in which the lecturer—Dr. Sterry Hunt—speaks of this matter, and also mentions the case of some fish remains from certain Mezozoic slates in Bohemia, which were found incrusted by crystals of Sulphide of Copper, which also occurred penetrating the stems of ancient trees in the sandstone of New Jersey. He also refers te the "Turf" mine in Wales, in which the water draining from a Copper Mine, so impregnated the turf of a neighbouring bog, by which the copper was reduced, that it proved a profitable working. (He says, Copper " Mine ;" I believe however, that the copper was derived from metal disseminated through the neighbouring rocks; attempts to find the supposed lode were unsuccessful.) If the organic matter be present in suitable quantity or condition, deposits of metallic sulphides, &c. may be formed having no trace of the original reducing agent.

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*May, 1872.

Iron pyrites is stated* to be slowly decomposed by water and air, with the aid of a certain amount of heat, with the resulting formation of hydrous oxide of iron, and sulphuretted hydrogen; this reaction may possibly have been concerned in the production of the large deposits of "Gossan" found above the masses of pyrites in various countries, although the chief cause is no doubt slow oxidation and formation of sulphuric acid.

Shales and Clays are frequent depositaries of Iron pyrites, it being in sedimentary strata or in conjunction with them that it chiefly occurs. According to Méné (quoted by Lunge), the pyrites from Volcanic formations contains no water, that from sedimentary strata both water and clay. There sometimes occurs amongst pyrites, a variety which detonates violently when thrown into a fire or kiln. This peculiarity is supposed by Lunge to arise from zeolites present in the ore, but if so, it is usually not apparent exteriorily; this occurs also frequently in coal pyrites, but I am disposed to think from the presence of occluded water, which may also be the cause in the other case.

Large amounts of copperas, or sulphate of iron, are produced by the oxidation of the pyrites in shale—generally of the coal measures—which is exposed to the air, and the resulting copperas dissolved out by water, and crystallized. Lunge states that in 1874, 10,000 tons of pyrites picked from coal was utilised in this country, most of it probably in this manner. At various Collieries the shale is thrown into heaps, upon which the rain falling dissolves out the sulphate of iron resulting from slow oxidation of the pyrites, which solution is evaporated and crystallized. This oxidation results in the formation of various sulphates in the coal mines, e.g. sulphate of soda, which occurs in this district, and I examined recently a salt from some old workings of one of our President's pits, which consisted of a combination of Aluminium and Sodium Sulphates, with some Sulphate of Iron, apparently similar in composition to the mineral Mendozite, a sodium alum found in South America and Japan, and probably also in other places.

**Clermont* and Guiot "Comptis Rendus," Aug. 1879.

This Pyrites also, when we consider the enormous amount of coal consumed in this country, will be seen to be a source of very serious contamination of the atmosphere. Dr. Angus Smith, in a recent report* points out that if we take the coal burnt annually in Great Britain at 100 million tons, and assume that there is given out 1 °/o sulphur, this will burn at once to 2 million tons of Sulphurous acid, and slowly to 3 million tons of strong vitriol ; much of this acid is brought down by the rain falling in large towns. Coal Pyrites, when quite free from adhering matter, is stated to be usually very pure.

In the United Kingdom, the chief deposits occur in County Wicklow, where the Pyrites occurs in beds from 5ft. to 50 ft. in thickness, which overlay silicious clay-slate, and to which I shall again refer. In England it occurs in Cornwall and Devonshire, containing 25 to 35 per cent of Sulphur and some arsenic; during the year 1880 5,188 tons were obtained from these counties. In N. Wales there is a mine at Trefriw, where the ore (containing about 40 per cent of Sulphur) occurs in lower Silurian rock and in contact with a dyke of greenstone, the junction between the 'lode' and the adjoining rock is frequently clearly marked. The quantity produced is some few thousand tons per annum.

Pyrites, as before mentioned, is also obtained as Coal "brasses" of which, in 1880, the quantity was 5,240 tons, and at Cleveland, (North Yorkshire) there is a deposit used in a local works ; it is found, in fact, more or less, in almost all mining districts, and as crystals and nodules in clay and chalk. The total production in Great Britain during the year 1880, as given in the Mine Inspector's Reports was 16,000 tons.

The great deposits of Pyrites, however—i. e. those of the greatest importance industrially—occur in a tract of country at the southern part of the Spanish peninsula, where the ore occurs in large lenticular masses or lodes and where

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*Inspector's Report, 1875-76.

the supply appears practically inexhaustible. I will refer to this district and its mines more fully immediately; before then we will glance at the smaller, although still important deposits of the continent. There are various deposits some of considerable extent, in America, at Vermont, Missouri, Lake Superior, &c., and also in Canada, but about which I have been unable to obtain very precise information.

The ores may be separated into "cupreous" and "non-cupreous," but for the present purpose we need not do so, as the bulk of the Pyrites which is used commercially is of the "cupreous" variety, probably somewhat more, than two-thirds —although frequently not containing more than 2 per cent of copper. Ores which are free from copper are usually free from Arsenic as before stated, and are used by a few manufacturers for the production of Sulphuric acid free from that element.

The most important of the French deposits are those of Chessy and of Sain-Bel, near Lyons which contain 45 to 48 per cent of sulphur with very little arsenic; (the Chessy ores also 1 to 2 per cent of copper,) they are the most largely used, but there are also smaller beds at Alais, Le Soulier and Ardèche. I regret that I have no particulars of their mode of occurrence.

In Belgium, which in 1872 produced 41,000 tons, the pyrites is usually obtained as a by-product in the getting of lead and zinc ores, in the provinces of Liège and Namur, it is of a semi-crystalline and not very compact nature.

Italy has deposits in various places, some varieties containing as much as 3.75 per cent. of Nickel (that from Pallanza ½ to 1 per cent.) The ore appears frequently to consist of an aggregation of large and small crystals.

At Agordo, in the Venetian Alps, there is also a deposit, and in Hungary there are lenticular massess of 20 fathoms in width, parallel to the cleavage of the enclosing clay-slate, which are combined with zones of slate highly impregnated with *pyrites.*

In Switzerland it occurs in the Canton of Wallis, and in

Sweden there exist large quantities in conjunction with copper ore at Fahlun, the deposits being associated with gneiss, clay-slate, mica-slate, and talcose slate, they also are lenticular in form, and of great width.

Norway has large beds which are not now worked so much as formerly, owing to the small amount of sulphur which many of them contain (35 to 40 per cent.) The chief mines are those of Ytteröen, which supply 6000 to 8000 tons per annum; other deposits occur near Drontheim, Bergen, &c.

In Germany, the most important bed is that of Meggen, in the Siegen district, in Westphalia. Lunge states that "it occurs with heavy spar in the so-called "Kramenzel" and is known for a length of 2000 fathoms, the thickness varying from $\frac{3}{4}$ to 3 fathoms. The mass of ore above the bottom of the valley is estimated at $4\frac{1}{2}$ million tons, how far it extends below the bottom of the valley is unknown."

It contains $45\frac{1}{2}$ per cent. of sulphur, with Zinc and traces of Thallium and Cobalt.

The bed of Schwelm, in Westphalia, is in the Devonian formation, and has a thickness of 10 to 33 feet over a surface of 150 acres, which is covered by rich Iron ore. It is not a very compact pyrites, and contains more or less clay.

On the Island of Wollin, a pyrites bed is found in a stratum of marl, belonging to the chalk formation.

There is also a deposit at Rammelsberg, near Goslar, in the Harz, which has been described at length by Professor Von Cotta, in a German magazine* from which a translation is given in the Mining and Smelting Magazine of 1865. The account there given is of considerable interest, not only of itself, but also from the resemblance in some respects which the deposit bears to those of Spain and elsewhere. He (Von Cotta) says "The Rammelsberg mine, situated near Goslar, is composed of the three lowest members of the Devonian formation of the Harz—the Wissenbach slate, the Calceola slate, and the Spirifera sandstone. Here however, the order is reversed, the Wissenbach slate being the lowest, and the

*Berg-und Hütten, No. 45, 1864.

Spirifera sandstone the uppermost member of the series, a position that can only have been brought about by some great inversion." "The pyrites deposit is situated in the Wissenbach slate, which forms the base of the mountain, and which here consists of true clay-slate, very generally used in the neighbourhood for roofing purposes."

After some remarks on the stratification, &c. he concludes "that in the Wissenbach slate the cleavage and stratification coincide, which is a point to be borne in mind when considering the deposit."

Various observers appear to have come to the conclusion that the deposit is a bed, though hardly of the kind as usually understood; it occurs in the clay-slate (as shewn), the hanging wall having been originally the foot-wall, as pointed out by the author. The depth varies, and the width of the undivided mass of the deposit is reckoned at 35 to 40 fathoms. Considering the difficulty of supposing it to be a bed—the ramification into the hanging wall, alone, almost doing away with the idea—he examined the deposit further and found that in reality it consisted of a number of small lenticular masses of pyrites, separated by thin partings of clay-slate, and consequently goes on to say that "the outer limits of the whole deposit, as it is usually represented, are nothing more than the margins of an agglomeration of masses of ore, which together are rich enough to be mined profitably, but whose individual shapes may differ widely." (It seems, however, that they are usually lenticular.—See sketch.)

As to the origin of the deposit, after suggesting various hypotheses and the difficulties in the way of accepting them,—such as contemporaneous origin; deposition from solution; replacement of the slate by the pyrites; (which, together with Iron, Copper, and Lead, contains traces of eleven other metals,) &c.,—he speaks of the similarity of various deposits, pointing out that at Agordo the deposit occurs in slate and is almost identical in composition with that at Rammelsberg.

At Schmöllnitz, in Hungary, the ore forms in lenticular masses, 20 fathoms in width, and parallel to the cleavage of the enclosing clay-slate.

At Fahlun the large lenticular masses are traversed by zones of slate.

At Rio Tinto, in Spain, the deposits are found on the borders of Silurian clay-slate, and at Domokos-Poschorita, in Transylvania, the enclosing rock is mica-slate passing into clay-slate. The pyrites here can be followed for 20 miles on its line of strike, but is not more then a few feet thick.

Finally, he comes to the conclusion "that these lenticular impregnation masses have gradually penetrated to their present position, partially assuming the texture of the dislodged masses of slate which they have replaced." He admits, however, that this supposition involves a great many difficulties and is far from being a satisfactory explanation.

Turning now to Spain, we find there, and in Portugal, a zone of pyrites country stretching from the province of Seville and running parallel to the Sierra Morena right through the latter country. This metalliferous zone has a length of about 30 leagues and a width of 5 leagues, within which area all the mines are situated.* The prevailing rocks of the country are Silurian clay-slate and crystalline slates, (talcose and micaceous) but felsite-porphyry and quartzite dykes have broken through the slate, and it is in the neighbourhood of these that the beds are found. The strata rear up at high angles and are much contorted, but a general N.E'ly. and S.W'ly. strike can be traced.

The shape of the deposits is that of rudely lenticular pockets, the longer axes running parallel with the strike of the beds adjoining, which is usually clay-slate or greenstone, the latter frequently forming one wall or "sahlband," the other consisting of altered slate or porcelainized rock. They are of enormous extent and are usually marked by depressions in the surface of the ground between the two walls, and by the overburden of "gossan," chiefly consisting of decomposed "country," oxide of iron, and of matter deposited from the rocks above. In many cases this mass of decomposed mineral, &c., together with, probably, oxide of iron deposited from

*Lunge.

solution, reaches a great thickness; it averages, perhaps, 40 feet, but varies from 20 to 160 feet. They usually decrease in thickness as they go down, and some are stated to have ended in a boat form; the ore is usually very homogeneous, containing 48 to 50 per cent of Sulphur, and 2 to 40 per cent of Copper, but ore containing more than 8 to 10 per cent of the latter is only found in small zones within the larger masses; the bulk of the ore imported to this country contains from 2 to 4 per cent.

Many of them extend to an unknown depth and are of great width and length, the San Dionisio lode of the Rio Tinto Co. having been proved to be 2½ English miles long, and one of the lodes at the same mine, in one part, is no less than 110 yards thick.

I am indebted to an interesting paper by Mr. Green, in the Quarterly Journal of Science, 1868, for some of the particulars of the chief lodes, which I am able to give, and also for the sketches (except that of Buitron, which is from a paper by S. H. Pattison, in the Geol. Mag., 1872).

In it he gives an excellent description of the physical and geological features of the district, bnt which time will not allow me to recite.

In regard to the mines (which were largely worked by the Romans and Phœnicians for copper), beginning at the West, we have the San Domingo (Mason and Barry), in the province of Alemtejo, Portugal. Here the deposit is of the usual lenticular shape, and between 500 and 600 metres long by 70 metres broad at the widest part; it is split up by several "horses" of slate. The ore is of the usual composition and of superior quality, it being in much demand: Galena and other minerals are sparingly present. It is now worked "open-cast," as are also (I believe) all the mines of this district. The plane of separation between the ore and adjoining rock is distinctly marked, and hades to the North at an angle of 45° to 80°, the friction producing frequently most beautifully polished "schlickenside." In contact with the mineral are 2 or 3 inches of soft quartzose rock, then hard

porcelainized rock, and beyond this the slate. The altered rock seems to be the result of great heat action, and the schlickensides, &c., would point to great movement and sliding of the rocks, although one is inclined to think that other action than that of friction alone has been concerned in producing the mirror-like polish—so free from striation—of some specimens; may not the action of water in joints or even electric currents have influenced their formation?

Next in order is the "Rio Malagon," a mine recently started (or rather a new Company formed to work an old mine), for the obtaining of a rather mixed ore of lead, zinc, copper, and silver; it has the usual characteristics, viz., lenticular masses of ore in a schistose formation of Silurian age. The schist becomes metamorphosed at its contact with the ore deposits.

The Tharsis mine consists of four large masses of ore, all clearly pointed out by surface indications; the Gossan here reaches at some spots a thickness of 130 feet and is believed to average 110 feet. The form of the deposits is shewn on sketch. It is exceedingly prosperous; the total amount of mineral raised in the year ending March, 1881, was 378,000 tons; in 1880, it was 438,500 tons. The whole of this is not exported; however, a large amount is treated on the spot for copper, as is also the case at the San Domingo and Rio Tinto mines.

This last (Rio Tinto) is the largest of the pyrites companies (Buitron, I believe, is the smallest), and owns a property containing nearly 5,000 English acres in one connected tract. It was formed in 1873 by a combination of capitalists. The mines are situated about 50 miles from the port of Huelva, in Andalusia, and consist of 3 lodes running E. and W. The Northern and central ones are divided by a wedge of porphyry, for the greater part of their length; the Southern lode being of greater length than the other two.

Both the North and South lodes are now worked, the latter "open-cast;" the former has only just recently been attacked and is estimated to contain something like 100 million tons of ore.

There was raised in the year ending May, 1881, over 900,000 tons; two-thirds of which were consumed or laid down for consumption "on the premises," for the extraction of copper, silver, and the small amount of gold which exists in the ore. The number of men employed at the mines is about 7,000, and the magnitude of the concern may be judged from the fact, that at the port of Huelva, the company own a loading pier and viaduct costing £145,000, and which is capable of shipping some 5,000 or 6,000 tons of ore per day.

(The paid-up Capital of the three companies—"Mason and Barry," "Tharsis," and "Rio Tinto,"—is stated to be nearly 5 millions, and the present value will be very much larger than that.)

The mines of Wicklow must not be omitted from an account of pyrites deposits, although time will not allow a very full reference. They are not now worked to any great extent, the ore being beaten out of the market by the richer mineral from Spain and Portugal.

The deposits occur in silicious clay-slate, in a belt of country about ¾ of a mile wide, running N. by E. for about nine miles from the north flank of Croghan Kinshela, near Arklow.

They were very fully reported upon in the year 1853, by Prof. W. W. Smyth,* from whose description chiefly, I have taken the following particulars.

The slates in question, which are considered to be Silurian, are thinly laminated and very uniform in strike and dip, although passing through many gradations in mineral composition. Towards the S. Western end of the district, two deposits occur; one of copper, and one of iron pyrites; which run parallel at a small distance apart, and varying in width from a few inches up to several feet. The first mine of which he (Prof. Smyth) speaks, is Ballymurtagh, where both copper and iron pyrites are produced, the latter marked, as is the case in Spain, by huge projecting masses of "gossan" or hydrous peroxide of iron. The pyrites dips with the slate, is

*"*On the Mines of Wicklow and Wexford.*" Records of S. of Mines.

about 12 feet in width, and ceases by gradual interlamination with the walls of clay-slate. (In the Spanish deposits, the walls are usually distinctly marked, these appear to resemble more the Rammelsberg "lodes," as described by Von Cotta.) At one part the deposit is marked by a cross fissure at nearly right-angles to the lode, consisting of copper pyrites and quartz; and it is important to notice that the pyrites is crossed in several places by deposits of Copper ore of limited length, and known as T's by the miners; (Tigroney mine) they seem to prove clearly that other forces than simple aqueous deposition have been at work. More towards the N.E., in the mine of Cronebane, the deposit consists of sulphide and black oxide of copper, passing in depth into pyrites.

Still further to the N.E. is the mine of Connary, which also has copper ores above and iron pyrites below in ribs 8 to 10 feet wide.

The mine of Ballygaghan is also of importance and presents some interesting features, which, however, must be passed over; I may mention also that much copper has been obtained from the mine waters of the district by precipitation, it existing in solution as sulphate, owing to decomposition of the ores.

Throughout all these mines the pyrites is in conjunction with clays and soft slates, and Prof. Smyth observes, "that although these ore-deposits present most of the characteristics of bedded or stratified masses, such as their conformability to the beds of slate; their freedom from vein-stone; their laminated structure; and the gradual blending, in most cases, with the adjoining strata; yet the mode in which they appear to cross the strike of certain beds, and the existence (among other phenomena which he mentions) of the T shaped fissures, induce the belief that they must be regarded as lodes or true metalliferous veins of a peculiar order."

About the year 1851, the exports of pyrites (the bulk of which contains 30 to 35 per cent of sulphur, a small quantity being upwards of 40 per cent,) reached a total of 100,000 tons per annum, but this has gradually fallen off and the yield is

now small comparatively, the ore only being used in a few works in Ireland itself. In 1880 the production of the mines was 8,500 tons.

When considering the modes in which we find the great deposits of pyrites to occur, one is struck by their similarity; the one fact of their general connection with more or less metamorphosed clay-slate being very prominent, and in searching for an explanation of their origin, one is led to inquire whether any such deposits are being formed at the present time. As far as I am aware, no such processes are actually known to be going on now; probably similar causes are at work producing similar results, as it is a generally received canon of Geology, that the course of geological and mineralogical change and deposition is the same at the present as it has been in the past; yet, upon looking at these "beds" or "lodes," it seems so difficult to account satisfactorily for them that, for the present, I will refrain from theorising and leave the problem to be dealt with by abler hands.

It may, perhaps, be of interest if I briefly glance at the commercial importance of our guest. Iron Pyrites is not used as an ore of Iron, (primarily) but of sulphur, and it is from it that the great bulk of the suphuric acid of commerce is produced.

Before the year 1838, sulphur had been exclusively used for the manufacture of this acid, but in that year the price was nearly trebled, owing to a monopoly granted by the King of Naples. This led manufacturers to turn their attention to other sources of sulphur, and the use of Pyrites so rapidly extended, that in less than 40 years afterwards, (1874) no less than half a million tons were imported into Great Britain for the purpose of this manufacture. Details concerning it are unnecessary, but I may say, shortly, that the ore is broken into small pieces, burnt in kilns, and the resulting sulphurous acid gas passed into leaden chambers, where, with the aid of steam, &c., it condenses as sulphuric acid.

The enormous quantity manufactured and used, chiefly —*though by no* means entirely—in the soda trade, may be

seen from the fact that the 500,000 tons of pyrites imported would equal some 650,000 tons of concentrated oil of vitriol, if worked up in that form.

As stated, it is at the foundation of the great Alkali trade of this country, it being used for the making of sulphate of soda, which is the first step in the production of the great bulk of the soda-ash, and of all the caustic soda made, and which it is of immense importance should be produced cheaply for the manufacture of soap, glass, paper, and for many other purposes; the sulphuric acid itself, being used in the manufacture of artificial manures; the treatment of oils and fats, and of the various products of coal tar, aniline colours, &c.

(In the year 1880, 400,000 tons of pyrites were used for the production of soda alone, independently of that used for the production of sulphuric acid for other purposes.)

After yielding its sulphur in the form of sulphuric acid, the "cupreous" pyrites cinders are generally treated for the extraction of copper, previous to which however the silver, to the amount of about 18 dwts. per ton, and also a small amount of gold, is extracted by what is known as "Claudet's" method, by which it appeared on treating a large quantity of burnt ore at a Widnes works, that 0.65 oz. silver and 3 grns. of gold, per ton, might be extracted from Spanish pyrites and with considerable profit* After these metals have been removed there remains only the oxide of iron, with some silica, &c., and this is finally worked up for the making of iron, and the lining of iron furnaces; so that there is not much of the original ore left to be utilised.

I append typical analyses of the Spanish ore (San Domingo) by Claudet, they will serve to shew the average composition of that which is so largely burnt in this district; a great part of the sulphur in which, I may mention incidentally, after having done its work as sulphuric acid through various processes, is now lost in the heaps of alkali waste to be seen in the neighbourhood of St. Helens and Widnes. As improved methods are devised for recovering

*Phillip's "Elements of Metallurgy."

this sulphur it is quite possible that the use of pyrites may diminish and manufacturers revert to their old friend.

ANALYSES of Spanish pyrites, (San Domingo mine) Claudet.

	Raw.	Burnt.
S.	49.00	3.76
As.	.47	.25
Fe.	43.55	58.25
Cu.	3.20	4.14
Zn.	.35	.37
Co.		trace.
Ag.		trace.
Pb.	.93	1.14
CaO	.10	.25
H^2O	.70	3.85
Silicious residue.	.63	26.93 Oxygen, loss, &c.
Oxygen and traces of various metals	1.07	1.06 Insol. matter.
	100.00	100.0

PRODUCTION of the WICKLOW MINES in 1880.

Cronebane.	1,089.
Ballymurtagh,	1,858.
Tigroney,	5,338.
Other mines,	237.
	8,522 tons.

NOTE ON FERRUGINOUS BANDS IN THE SANDSTONES OF THIS DISTRICT.

By A. Norman Tate, F.I.C.

In a recent paper (see page 25,) I referred to the theory of the formation of iron ore deposits by the concentration of the iron disseminated in minute quantity in different strata by the action of water containing in solution organic matter and carbonic acid. The ferruginous bands and markings in many sandstones and other rocks are good examples of the concentration of the iron disseminated through them, and although the concentration is far less than in the case of iron ore deposits, it is yet interesting and instructive to note what is now taking place under circumstances that admit of close examination, analysis of specimens, &c. The highest proportion of iron I have found disseminated in any sandstone of this district is 1.25 per cent, but this is much more than is found in the lighter coloured sandstone, which usually do not contain more than from 0.05 to 0.5 per cent. In a small quarry in a lane leading from Storeton Road to Prenton, I noticed a short time since, a very good example of the action referred to. The upper portion of the rock, to the depth of about two feet, is strongly impregnated with organic matter, much of which is soluble, and the presence of carbonic acid in the water filtering through it is also readily detected. This portion of the rock contains 0.50 per cent of iron, and 1.8 per cent of organic matter, and, at the time I took the sample, held 9 per cent of water. Below this, to the extent of about eighteen inches, the rock is less coloured by organic matter and contains 0.65 per cent of iron, whilst, in a lower layer, of a deep yellow colour, there is 1.5 per cent, but below this there is a thin band much darker in colour and more shaly in character, in which there exists iron to the extent of 14.7 per cent. Where this band now exists there has evidently been a

slight fissure, and the washing out of the iron from the surrounding rock has no doubt led to subsequent deposition and concentration in this fissure. Most sandstones and other rocks afford similar examples, and other ferruginous markings also indicate the percolation of water containing iron in solution. The forms which some of these markings assume are often curious, and indicate a very tortuous course taken by the water, the direction being determined by the presence of clay bands, nodules, pebbles, or by portions of rock harder and less porous than others. In the samples now analysed manganese was present only as a trace; but this may sometimes be met with in larger proportion associated with the iron in little pockets and bands in the sandstones. The filtration of water through other rocks and strata, with the formation of similar deposits of other chemical substances, is often worth notice as illustrations of possible modes of formation of many minerals.

Field Meeting, 11th March, 1882.

The first Field-Meeting of the season was held on the above date, at Hoylake and West Kirby, conducted by Mr. Isaac E. George and Mr. C. E. Miles, At Hilbre Point. Mr. George directed attention to the existence of glacial striæ on the sandstone, which have hitherto been unobserved at this spot. The ice-scratches, though not deep, are distinctly marked, and trend in a direction almost due north and south. Mr. Miles gave an account of the leading characteristics of the Triassic rocks in Cheshire.

LIVERPOOL GEOLOGICAL ASSOCIATION.

3rd April, 1882.

At the Ordinary Meeting, held this date, at the Free Library, Mr. Henry Bramall, M. Inst., C.E., President, in the Chair, the following were proposed as Members :—

Messrs. R. Hughes Jones, Old Castle Buildings, Preeson's Row; John Storey, 27, Gibson Street; and Richard McCully, 88, Wordsworth Street, Liverpool.

DONATIONS.

Abstracts of Proceedings of the London Geological Society, from Mr. G. H. Morton, F.G.S.; Proceedings, 1880-81, from the Manchester Geological Society; Report for 1881, from the Lancashire and Cheshire Entomological Society; Annual Report, for 1881, of the Liverpool Free Public Library, Museum, and Walker Art Gallery, from Mr. P. Cowell, Librarian.

Abstract of a Paper read :—

"VOLCANOES,"

By Daniel Clague.

Volcanoes have ever been associated with the wonders of the world, and it is not surprising that in these days of adventure and enquiry, a railway should have been carried to the top of one, so that adventurous travellers may see for themselves the mountain in labor, bringing forth molten rock.

The evidence of eye witnesses of a volcanic eruption is of a most graphic character. Valetta speaks first of "internal murmurs in the lowest depths of the mountain," then "smoke appeared by day and a flame by night;" at intervals "substances were shot up with a sound like that of artillery;" then "it threw up ashes;" to these succeeded "showers of stone." Soon after, "a torrent of burning matter began to

roll down the side of the mountain, at first with a slow and gentle motion, but soon with increased velocity. The matter thus poured out, when cool, seemed upon inspection to be vitrified earth, the whole united into stony hardness; but what was more particularly observable was that upon the whole surface of this material a light spongy stone seemed to float, whilst the lower part was of the hardest substance of which our roads are usually made."

Bishop Berkley bears similar testimony to the phenomena of an eruption, only adding more details.

When, to these thunderings, rumblings, and fiery vomitings, we add that many curious enquirers into these phenomena have lost their lives through their temerity, and that whole cities and districts have been destroyed by showers of ash, or streams of lava, it is not surprising that in an unscientific and superstitious age, men attributed these things to supernatural powers.

In these days we look upon these wonders with a more critical eye. Modern students of nature have learned wisdom by the mistakes of their predecessors, and by studying volcanic phenomena when the forces were working more mildly, they have been enabled to study the subject more perfectly, to examine the supposed flames, to analyze the smoke, to understand the fearful sounds, and to test the character of the lava streams; and still further, by an examination of the remains of extinct volcanoes, the very construction of the mountain has been revealed.

We will now, with these lights, consider an ideal volcano. It is a mountain of (more or less regular) conical form, with a cup-like crater at the summit; this crater surmounts a perpendicular neck or tunnel which penetrates the mountain, and is connected with the heated matter under ground. The mountain is composed of successive layers or strata of material roughly parallel to the sides of the mountain. This led the early geologists to support the theory of "*elevation craters*," by which they meant that the originally horizontal strata of the earth, forced up at a given point by internal

forces, produced a mountain, the sides of which had originally been an horizontal plain. Such, however, is not the case, for the strata of a volcano is composed of the ash and lava and other matter ejected from the crater which, falling round the mouth, would increase with every discharge, till in this manner considerable mountains have been formed. In one case, Monte Nuova, a hill 440 feet high, was formed in one eruption lasting over two days and two nights; in other cases, such as Etna and Chimborazo, mountains having a base of 30 to 100 miles, and an elevation of from 10,000 to 25,000 feet, have been formed as the result of many eruptions.

The material ejected from volcanoes is variously named according to its texture and composition. Perhaps I shall best make this plain by an illustration, which has frequently been used;—that of a furnace, in which the various minerals and rocks are in a molten state. The minerals, then, in our furnace may be Silica, Alumina, Magnesia, Lime, Iron, Potash, Soda, Manganese, and small quantities of other substances. These mixed together in varying proportions, and melted, will produce material similar to that of volcanoes. Now, let water be supplied to the hot molten matter, and the volcanic force is ready for operation.

As the minerals are melting, various gases are given off. They may be hydrochloric, sulphurous, carbonic, or boracic acids, sulphuretted hydrogen, hydrogen, nitrogen, ammonia; also the vapours of the volatile metals,—arsenic, antimony and mercury. These combined with watery vapour, find their way to the surface, and appear as light curling wreaths of vapour ascending from fissures in the ground.

Steam has been generated in too great a quantity to find sufficient escape in this manner, and becomes more and more compressed, till, with a tremendous explosion, it blows up into the air the matter that had choked up the crater; this material, falling back, rests upon the mountain, adding to its size.

The molten mass is now found to be seething and boiling, rising in the neck of the volcano, steam bubbles rise through

the mass, carrying with it the lighter portion of the material; the froth rises to the top, this gets blown away, and cools while the contained gases and steam are escaping, leaving a beautiful vesicular glassy substance called pumice.

Sometimes, however, the matter is only half molten, still sufficiently plastic to be expanded by the heated vapour; this coarser scum, when carried away, is known as Scoria, because of its cindery appearance. Much of this Scoria, falls back into the crater, is broken up into fine dust, and again ejected, and, when caught by the wind, is often carried to a considerable distance, falling at times in showers of dust, producing a "darkness that may be felt," burying gardens, vineyards, and even cities, in common ruin.

Still, the furnace is seething and boiling, and bye and bye, in the midst of a grand display—(steam being shot up into the heavens, luminous with reflected light, and grand with electric flashes)—the lava overflows, and flows down the side of the mountain, a stream of molten rock. Soon the surface cools, and forms a crust over the still hot and semi-molten mass beneath, and adventurous souls climb and walk on it, at the hazard, however, of stepping upon some weak place,—slipping in, and——never returning to give a report of their fiery adventure. Through this crust the steam and gases are escaping, and when a solidified portion of this crust is examined it is found to be vesicular and full of small holes.

A curious fact is, that lava streams have been known to flow up hill in consequence of the outer surface cooling rapidly, and forming a tube, through which the fluid matter continues to flow. This accounts for the contests which have arisen amongst the inhabitants of the valleys towards which the lava stream was flowing, each party being anxious to tap the stream on the side furthest from their own home. An instance of this is mentioned by Lyell in his "Principles."

We will now suppose that sufficient time has elapsed for the whole mass to cool, and be converted to stone. If in our *ideal lava* flow we could get a good section, we should find that *near the surface*, where the lava had cooled rapidly, it is of a

glassy texture, breaking with a conchoidal fracture, and is known as *Obsidian*. Lower down, where it has cooled more slowly, the glassy character is lost, and instead we have a fine grained *compact* rock known as *Rhyolite;* still lower, where the cooling process has been slower, we meet with a *crystalline* rock, made up, not of perfect crystals, but of small crystal facets, as if a lot of young crystals were each struggling into existence; still lower, where the cooling process has been slowest, we find the crystalline facet larger, and many crystals are well developed, some of them of considerable size. These two last specimens would be called *Trachyte*, and *Porphyritic Trachyte* respectively.

In our volcano we notice that the ejected material is of a light colour, and when portions of it are sufficiently long exposed to the weather, the colour becomes still lighter; it weathers white or grey. But a friend close at hand assures us that he has seen similar eruptions in other places where the ejecta are much darker in colour, and also much heavier, and which weather red or brown, or even black, and in these basic lavas the same gradations of texture have been observed, that we notice in our light-coloured acidic lavas.

Some of the industrial products of volcanoes are pumice, sulphur, and boracic acid. The consolidated lava (stone I now call it) is not extensively used for building purposes, being too *short* and brittle, but it is largely used for road making, as we may see both in our country roads and city streets.

What do volcanoes teach us respecting the interior portion of the earth ?

Certainly not that it is a mass of molten matter enclosed in a crust of uncertain thickness. Volcanoes are not so many outlets of a common reservoir; were it so, we would expect to find the ejecta of volcanoes to be of the same composition in all parts of the world. Instead of this, we find that the lava of different volcanoes differs very materially; for instance, the *lava of Hawaii* is very different from that of Vesuvius.

Further, if volcanoes were all fed from a common reservoir, we should expect to find the lower craters overflowing before the higher ones; but the fact is that where there are neighbouring craters at different altitudes, as Mauna Loa, where there is a difference of 10,000 feet in the altitude of two craters, frequently the higher one is active whilst the lower one is quiet. These facts lead us to suppose that each volcano is supplied from a distinct reservoir.

With regard to the origin of the lava, several ingenious theories have been started to account for it; some have supposed that there are large cavities in the earth containing molten matter, relics of the time when the whole earth was molten, and that yielding to external pressure, this matter is forced upwards and so produces the phenomena we have been considering.

Others allege that the intense pressure to which the lower rocks are continually subjected is sufficient to generate heat enough to melt the most intractable rock, and therefore in the lower parts of the earth there is a continual melting process going on, followed by a cooling and hardening process, as the pressure is relieved by an eruption, either to the surface giving rise to a volcano, or into some subterranean cavity, causing, it may be, an earthquake.

Again, the idea has been submitted that as gases of various kinds, and water charged with a variety of elements, pass continually through the earth, they bring together elements which, becoming chemically united, result in new compounds, accompanied by heat enough to reduce the rocks into a molten condition, and so produce the phenomena both of earthquakes and volcanoes.

Probably the true explanation of volcanic energy is to be found in one or other of the two latter theories.

Volcanic energy may be exerted without showing itself in the form of eruption; it is not difficult to conceive of the rocks being heated to a considerable degree, yet falling short of that melting point which results in eruption; in such *cases the rocks must* expand; this they do to such an extent

as to produce contortion and compression, so that rocks once soft and incoherent, become indurated and contorted; and also the expansion upwards produces elevation of land, such as is observable in many parts of the world, notably in Sweden and South America; of course when the rocks cool again they will contract, and in *some* cases this will cause a corresponding subsidence of land.

In all parts of the world there are traces of volcanic action; active volcanoes are found in Iceland, Europe, Asia, Africa, and America; in New Zealand and the Malay Archipelago, and in the South Sea Islands; and in many countries where now active volcanoes are unknown, there are the remains of ancient volcanoes, long since burnt out. Along the west coast of Scotland, in the north of Ireland, and the Isle of Man are remains of such old volcanoes; Cumberland, Derbyshire and Wales also give their testimony to volcanic forces having been active in our country in ages gone by.

In the Auvergne district, in France, hundreds of extinct cones are to be seen; also at Eifel, in Germany; in short, it would be tedious to enumerate the sites of active and extinct volcanoes; the world is full of them. When, then, we add to these the great, but slow, land movements which have been experienced all the world over, we begin to realise what an important geological factor we have in volcanic energy.

The world is full of denuding influences; the land is continually wearing away; but in volcanic force we have a counteracting agency, indurating the rocks, so enabling them the better to withstand the denuding agencies at work, and by an upheaval of the land, counteracting their destructive work.

Thus, interesting as our subject is to those who study the general phenomena of Nature, it is doubly interesting to those who are specially engaged in the study of Geology.

LIVERPOOL GEOLOGICAL ASSOCIATION.

Field Meeting, 11th March, 1882.

The Annual Easter Excursion was held at Buxton. The party visited, amongst other places, an interesting section, showing that, at this locality, the volcanic rock called "toadstone," appeared to have been deposited upon a land surface ; also Poole's Cavern, with its fantastic stalactites and stalagmites ; and the Valley of the Wye, where the geological features of the canon-like gorges, so noticeable in the district, were observed and their formation discussed.

1*st* *May*, 1882.

At the ordinary Meeting, held this date, at the Free Library, MR. CHARLES E. MILES, Vice-President, in the Chair, the following gentlemen, proposed on 3rd April, were elected as Members :—

Messrs. John Storey, R. Hughes Jones, and R. McCully.

Proposed as Members :—Messrs. Edward Smith, 27, Upper Parliament Street; George Robson, 66, Roscoe Street; J. C. Evans, 37, Ranelagh Street; and Robert Roberts, 9, Northumberland Terrace, Liverpool.

Abstract of a Paper read :—

"FOSSIL HORSES,"

BY ANTHONY W. AUDEN.*

The mammalian skeleton consists of an axis and appendages. The axis, or vertebral column, is perforated by a bony

***The Paper was illustrated by a collection of osteological specimens kindly lent by Mr. T. J. Moore, Cor. Mem. Z.S.L., Curator of the Museum**

canal (neural canal) for the passage of the nervous mass, and spinal chord, and it is made up of certain bony segments called vertebræ.

The appendages consist of two pair (the anterior and posterior limbs). The anterior limbs consist of a chain of bone, viz. the scapula, humerus, ulna, and radius, carpals, metacarpals, and phalanges. These bones are variously modified in different forms of life, but the general ground-plan is the same. The wing of the bat, paddle of whale, hand of mole, foot of cow or horse, or hand of man, are all built up from the same elements. In the order Ungulata, to which the horse belongs, this modification is found in various degrees, but may be divided into two types or sub-orders, the Artiodactyles, or even-toed, as sheep, camels, &c. (in which the foot is found to present a bilateral symmetry, the central line of which passes between the third and fourth toes), and the Perissodactyles, or odd-toed group, which possesses the third toe symmetrical in itself; the other toes, when present, are paired, but not symmetrically.

To this division belongs the Rhinoceros, Tapir, the Horse and its allies. The Tapir and Rhinoceros have the ulna and radius distinct. The Horse has them not only united by bone but a portion of the ulna is absent. The Tapir has four toes, the Rhinoceros three, and the Horse but one and the rudiments of two others.

The specialized points in the horse are the above-mentioned points in the limbs, the complete encircling of the orbit by bone, and the form and structure of the teeth. In nearly all early Tertiary mammals the number of teeth was forty-four; the horse has but forty, and a rudiment of an additional one in each jaw, which is early lost.

These points are of interest in connection with the fossil predecessors of the horse from the fact that certain forms have been found in which this rudimentary tooth was as large as the rest and was permanent; also in the orbit not being complete, which is the form in most early mammals and also in recent ones. The toes of the horse also can be traced back to a five-

toed animal through almost every gradation, as the following quotation from Prof. O. C. March's address to the American Association will shew :—

" The oldest representative of the horse at present known is the diminutive *Eohippus* from the lower Eocene. Several species have been found, all about the size of a fox.

" Like most of the early mammals, these ungulates had forty-four teeth, the molars with short crowns, and quite distinct in form from the premolars. The ulna and fibula were entire and distinct, and there were four well developed toes and a rudiment of another on the fore feet, and three toes behind. In the structure of the feet and in the teeth the *Eohippus* indicates unmistakably that the direct ancestral line to the modern horse has already separated from the other perissodactyles. In the next higher division of the eocene another genus (*Orohippus*) makes its appearance, replacing *Eohippus*, and showing a greater, although still distinct, resemblance to the equine type. The rudimentary first digit of the forefoot has disappeared, and the last premolar has gone over to the molar series. *Orohippus* was but little larger than *Eohippus*, and in most other respects very similar; several species have been found in the same horizon with *Dinoceras*, and others lived during the upper Eocene with *Diplacodont*, but none latèr.

" Near the base of the Miocene in the Brontotherium beds, we find a third closely allied genus, *Mesohippus*, which is about as large as a sheep, and one stage nearer the horse. There are only three toes and a rudimentary splint bone on the fore feet, and three toes behind. Two of the premolar teeth are quite like the molars. The ulna is no longer distinct, or the fibula entire, and other characters show clearly that the transition is advancing. In the upper Miocene, *Mesohippus* is not found, but in its place a fourth form, *Miohippus*, continues the line. This genus is near the *Anchitherium* of Europe, but presents several important differences. The three toes in each foot are more nearly of a size, and a rudiment of the fifth metacarpel bone is retained. All the known species of this genus are larger than those of *Mesohippus*, and none pass above the miocene.

" The genus *Protohippus*, of the lower Pliocene, is yet more equine, and some of its species equalled the ass in size. There are still three toes on each foot, but only the middle one, corresponding to the single toe of the horse, comes to the

ground. This genus resembles most nearly the *Hipparion* of Europe. In the Pliocene we have the last stage of the series before reaching the horse, in the genus *Pliohippus*, which has lost the small hooflet, and in other respect is very equine. Only in the upper Pliocene does the true Equus appear and complete the genealogy of the horse, which in the post-tertiary roamed over the whole of North and South America, and soon after became extinct. This occurred long before the discovery of the Continent by Europeans, and no satisfactory reason for the extinction has yet been given. Besides the characters I have mentioned there are many other in the skeleton skull, teeth, and brain of the forty or more intermediate species, which shew that the transition from the Eocene *Eohippus* to the Modern *Equus* has taken place in the order indicated. And I believe the specimens now at New-Haven will demonstrate the fact to any anatomist. They certainly carried prompt conviction to the first of anatomists who was the honored guest of the (American) Association a year ago, whose genius had already indicated the later genealogy of the horse in Europe, and whose own researches so well qualified him to appreciate the evidence here laid before him."

The conclusion is forced upon us that there is here a proof of a gradual mutation of species, or in other words, it is a demonstration of the truth of Evolution, for if not, how are we to account for these facts?

LIVERPOOL GEOLOGICAL ASSOCIATION.

Field Meeting, 29th May, 1882.

Held at Northwich, where a visit was made to the Witton Hall Rock Salt Mine, opened to the members by the courteous permission of the Proprietors, Messrs. John Thompson and Son. Mr. Thomas Ward conducted the party through his Salt Works and also on a tour of inspection round the locality, directing attention specially to the effects of the land subsidences.

Ordinary Meeting, 5th June, 1882.

Held at the Free Library, MR. HENRY BRAMALL, M. Inst., C.E., President, in the Chair. The following gentlemen, proposed at the last Meeting, were elected as Members :—

Messrs. Edward Smith; George Robson; James C. Evans; and Robert Roberts.

Proposed as Members :—Messrs. Charles Ricketts, M. D., F. G. S., 23, Argyle Street, Birkenhead; Thos. Ward, Northwich, Cheshire; Thomas Richard Fowler, 139, Crown Street; William Owen, 4, Comus Street; C. H. Green, 9, Lydia Ann Street; Lawrence W. Cade, 15, Upper Parliament Street; R. J. Finlay, Slater Court, Castle Street; T. R. Connell, 85, Edge Lane; R. F. Lister, 41, Deane Road, Liverpool; T. Littlewood, Vale Road, Woolton; and R. T. Jones, 21, Church Street, Egremont.

DONATIONS.

"Chemical and Geological Essays," Dr. Sterry Hunt, presented by Mr. A. Norman Tate, F.I.C.; "Geological Excursions round the Isle of Wight," Dr. Mantell, presented by Mr. Herbert Fox; "Geological Manual," De la Beche, presented by Mr. George Lewis; "Transactions of the Manchester Geological Society." Parts 14-15, from the Society, &c.

COMMUNICATION.

MR. D. CLAGUE drew attention to the phenomenon recently observed at Peel, Isle of Man, where not only the water of the River 'Neb' but also of the harbour, exhibits a deep reddish-brown colouration, due to the presence of carbonate of iron. This carbonate becomes rapidly hydrated on exposure to the air, and finally converted into a ferric-oxide in a state of fine division. Where the water is still, the oxide is deposited on the rocks, on boat bottoms, and on everything washed by the water. A point of interest in connection with the scarcity of organic remains in the Triassic and other similar formations, composed largely of red-rocks, is that a coating of the oxide was found to be deposited on the gills of the fish living in the river and in the sea round its mouth; this coating prevents the necessary oxidation of the blood of the fish, which results in their destruction. "Crabs, lobsters, eels, besides trout and other fish, have been found in hundreds, dying or dead, wherever the water has been affected"[1]. The mineral matter is obtained from the Foxdale Mines, through which the River Neb runs.

Abstract of a Paper read on—

"SALT,"

BY J. MEREDYDD ROBERTS.

Salt is a mineral which has played a most important part in the development of British commerce, and upon its cheap production many extensive manufacturing operations now depend. The uses of Salt are not confined to the manufacturer. Throughout the animal creation the craving for this substance seems almost universal. It is one of the necessary constituents of food, and is essential to health.

Chemically, Salt is anhydrous Chloride of Sodium; when pure, consisting, in 100 parts, of Chlorine 59·67 and Sodium 40·33. It crystallizes in transparent cubes, which are modified according to the manner of their formation, those crystals deposited from a slowly evaporated cold solution being the most perfect. At a low red heat it fuses, and at a white heat is volatilized. It is soluble in about three parts of cold water, and only very slightly more so in boiling water. A saturated solution has a sp. gr. of 1·205, the sp. gr. of the salt being 2·125. Salt contains as impurities other substances, such as the earthy chlorides and sulphates, together with water, these being mechanically mingled with the molecules forming the crystals. The chlorides of lime and magnesia, when present, have a tendency to make Salt deliquescent.

1 Vide "Isle of Man Times," 18th April, 1882.

Salt has a wide distribution throughout the world. It occurs naturally in solution in sea water, the waters of salt lakes and brine springs. It is also found in the form of deposits of Rock Salt, varying in thickness from a few inches to several hundred feet, and from which brine springs frequently emanate. In Europe, Rock Salt deposits occur in the Carpathian Mountains in the Provinces of Wallachia, Transylvania and Gallicia, (the celebrated Wieliczka mines being in Gallicia), the Austrian and Bavarian Alps, Western Germany, the Vosges, Jura, Swiss Alps, Pyrenees, the Celtiberian Mountains in Spain, Southern Russia, and the districts of Cheshire and Worcestershire in England. Among other places they are found in Nevada, Arabia, Persia, Beloochistan, Afghanistan, Hindostan, and also the Atlas Mountains in Africa.

From the great saliferous deposits of Triassic age occurring in the United Kingdom, and also on the Continent of Europe, it might be supposed that there had been a "Great Salt Age" in which Rock Salt was formed more freely than in other periods. Salt, however, like coal, does not necessarily belong to any geological epoch, and it is found in rocks of various ages, the deposits of Catalonia being *Tertiary*, Wieliczka *Cretaceous*, Bex *Lias*, Salzburg Alps *Oolitic*, while in the United States, brine is obtained from a red sandstone older than the Carboniferous age. Rock Salt may also be found at any altitude. The Salzburg deposit is 3,000 feet above the sea level, while at Wielickza it is 860 feet below the sea level. In Cheshire, Rock Salt occurs at Lawton 290 feet above, while at Winsford it is 90 feet below the level of the sea, the difference in this locality being due to faults or dislocations in the earth's crust.

Scattered over the earth's surface numerous salt water lakes are found, some being of large extent, and during the summer many become dried up, leaving the salt as an encrustation on their beds. These lakes are also not confined to any altitude. The Great Salt Lake of Utah has an area of 2000 *square miles*, and is 4200 feet above the sea level; the Dead

Sea lies about 1300 feet below the level of the Mediterranean. In Asia we have salt lakes at very high altitudes, Lake Namcho in Tibet being 15,000 feet above the sea level. These lakes are sometimes of very considerable extent, the Aral Sea covering an area of 24,500 square miles. The largest salt lake in the world, however, is the Caspian Sea, but neither the Aral nor the Caspian is very salt. Persia is a country rich in salt lakes, rock salt deposits, and saline encrustations.

Before a salt lake can deposit any crystals of Salt, the water requires to be saturated with over 27 per cent. of Salt. This per-centage, however, will vary with the amount of such other salts present in solution which affect the solubility of Chloride of Sodium. Salt lakes differ in their degree of saltness according to the amount of drainage of fresh water into them. The average saltness of the ocean is about 3½ per cent. The Caspian Sea has only about 1 per cent. of Salt. The Dead Sea contains 6½ per cent. of Chloride of Sodium, Lake Oroomiah, in Persia, 19 per cent., while the Great Salt Lake is a saturated solution of almost pure Chloride of Sodium. The waters of the Dead Sea contain more solid matter in solution than Lake Oroomiah, although the per-centage of Chloride of Sodium is small compared with that of the latter lake. This difference is owing to the presence of a large per-centage of Chloride of Magnesia in the waters of the Dead Sea—over 10½ per cent., Lake Oroomiah only containing ½ per cent. Bischof has shewn that as the presence of Chloride of Magnesia increases, when present in solution with Chloride of Sodium, the latter salt is, in consequence, rendered less soluble.

Of the Rock Salt deposits found in England, those occurring in Cheshire have been the most studied. The deposits lie principally in detached masses in two beds, covering an area of 30 miles in length, the greatest breadth of which is 10 to 15 miles. At Northwich the distance from the surface to the first bed varies from 96 to 159 feet. There it is about 90 feet thick and is underlain by a bed of indurated clay 30 feet thick, containing thin veins of Salt. Underlying the clay is another great bed of Salt Rock, which at Winsford

is 225 feet in thickness, and also has a bed of indurated clay beneath it. At Northwich the lower deposit is mined for Rock Salt. The upper 60 or 70 feet of salt is impure, much contaminated with clay, and is also stated to contain bituminous matter, it is then much clearer to the extent of 12 to 15 feet, and it is this part of the bed which is worked. Rock Salt from various mines is often observed to contain a quantity of gas confined under great compression. This was noticed to a remarkable extent in rock from Wieliczka and proved to be nearly pure Hydrogen.

The author dwelt upon the theory of the origin of Rock Salt, adopting that of the desiccation of salt lakes, the salt lake being in the first instance formed by a slowly upheaved area of land, enclosing the lake from the sea. In process of time, as the land rose higher, a river drainage from the new land surface into the lake would be commenced, bringing down clay, which would account for that impurity now found associated with Rock Salt.

Commercial Salt, besides being obtained from brine and Rock Salt deposits, is also obtained from the evaporation of sea water by solar heat. In this manner large quantities are made in France, Spain, the islands and shores of the Mediterranean, the North shores of the Black Sea, and the coasts of India; this form of salt is called Bay-salt. It is estimated that the annual production of solar salt in Sardinia is 20,000 tons, Austria 40,000, France 200,000, Portugal 250,000 and Spain 300,000 tons. The annual production of Rock and White Salt in England is now estimated at over 2,000,000 tons, and ranks third as an article of exportation. The exportation of Salt from the Mersey in 1870, was 884,024 tons; in 1880 it had increased to 1,201,496 tons, of which in 1880, 261,687 tons were exported to the United States, and 809,798 to the East Indies.

Further information on this subject may be obtained from—

The Parliamentary Report on the Salt Districts of Cheshire, by Joseph *Dickinson, F.G.S.*, 1873; "Chemistry as applied to the Arts," &c. Dr. S.

Muspratt; "British Manufacturing Industries; Salt," by J. J. Manley, M.A.; Papers by Thomas Ward on the "Great European Salt Deposits," and the "Salt Lakes, &c., of Asia," read before the Literary and Philosophical Society of Liverpool; Statistics published by the Salt Trade Association, &c.

Field Meeting, 17th June, 1882.

Held at Wallasey, Flaybrick Hill and Bidston.
Mr. Thos. Brennan conducted the party.

Near Wallasey old Church is an interesting Section of Lower Keuper Sandstone, shewing a curious development of cross-stratification, or "Current-bedding;" and also exhibiting signs of having been subjected to lateral pressure, producing contortion.

At Flaybrick Hill a fine rock-surface, about 200 square yards in extent, covered with glacial striæ, is exposed. Ice markings in this neighbourhood, were first discovered in 1862, by Mr. G. H. Morton, F.G.S.; since that date they have been frequently noticed. The direction of the striæ here is almost due N. and S. Some have been found trending S. 35° E. Prof. Ramsay adduces from this that the northern ice sheet, on reaching the high ground of Denbighshire and Flintshire, was deflected to the right and to the left; one part flowed across the plains of Cheshire the other scraped the coast hills of North Wales and overwhelmed Anglesea

Bidston Hill, the highest point in Wirral, affords a magnificent prospect, extending over the plain of Cheshire and the Valley of the Dee to the Snowdonian Range of Wales, and, on the north and west, commanding a fine marine view. The Conglomerate beds at the base of the Keuper are well exposed. A fault runs between Bidston Hill and Flaybrick Hill, and extends about two miles from N. to S. At Bidston Hill the beds dip to the E. and W., forming an anticlinal, as at Storeton Hill. The valley intervening between Bidston and Upton is of Bunter Upper Soft Red Sandstone, whilst at Upton (1½ miles from Bidston) the uppermost division of the Keuper (Red Marl) appears. The country between Bidston Hill and the Channel is chiefly alluvium (valleys of the Birket and Fender brooks) and blown sand. In a cutting on the east side of the Hill, good sections are exposed. Two faults are to be observed, and current bedding occurs on a similar scale to that at Wallasey.

LIVERPOOL GEOLOGICAL ASSOCIATION.

Ordinary Meeting, 3rd July, 1882.

Held at the Free Library, Mr. Henry Bramall, M, Inst., C.E., President, in the Chair. The following gentlemen, proposed at the last Meeting, were elected as Members:—

Messrs. Charles Ricketts, M.D., F.G.S; Thomas Ward; Thomas Richard Fowler; Willam Owen; C. H. Green; Lawrence W. Cade; R. F. Finlay; T. R. Connell; R. F. Lister; T. Littlewood; and R. T. Jones.

Proposed as Members:— Miss Emily Moore, 123, Richmond Row; Miss Emily Pratt, 15, Alt Street; Mrs. John Morris; 40, Wellesley Road, Liverpool; Mr. Samuel Henson, Mineralogist, 277, Strand, London, W.C.

DONATIONS.

"Volcanoes, what they are and what they teach," by Prof. J. W. Judd, 1881, presented by the President; Papers on the "Glacial deposits of the Clyde and Forth, &c.," and "On the chalk masses in the contorted Drift of Cromer; by T. Mellard Reade, C.E., F.G.S., F.R.I.B.A., presented by the Author.

Abstract of Papers read:—

I.

"SOME GEOLOGICAL NOTES ON A CORNISH BEACH."

By William Semmons.

The author described some of the leading features to be observed in a walk along Perran Bay, Cornwall, noting *en passant* the remarkable æolian deposit which has covered the two churches of Perran. The older church, built about 400, A.D., appears to have been covered about the year 1000, A.D., whilst the later church, built further inland, about the date of the destruction of the first edifice, was probably covered about six centuries later. The old church, constructed of stone, was discovered through the shifting of the sand dunes. It is of great interest to the archæologist, being probably one of the oldest examples of this description of building preserved *to us, and it* owes its existence to a geological accident. The

beach is composed of comminuted shells and small particles of quartz and patches of clay. The calcareous portion frequently assumes an oolitic structure, through the chemical action of the rain-water in dissolving and re-depositing it. In many cases the particles are quite firmly cemented together.

A little stream flows out of the valley on the shore, carrying in it, in solution, a small quantity of Sulphate of Copper, derived probably from the drainage of the copper mines. The effect of this stream has been to convert the Carbonate of Lime composing the shell fragments in the shore sand into Carbonate of Copper. The specimen produced contains probably about 15 per cent. of metallic copper. In another specimen some pebbles of quartz are found to be cemented together by this cupreo-calcareous carbonate, forming a conglomerate ; and, in a further instance, where the clay-slate is met with in angular fragments, the rock might be named a Breccia. On examining closely the specimen first-named, we find a section of the common *Littorina.* In the body whorl there has been room for the crystallising forces to act, and small but distinct crystals of *Azurite* (Blue Carbonate of Copper) occur. The author had frequently observed that when crystals of Carbonate of Copper have been found, the mineral has been *Azurite* ($2\ Cu\ CO_3 + Cu\ H_2\ O_2$), and not *Malachite* ($Cu\ CO_3 + Cu\ H_2\ O_2$.) The great interest in this Perran specimen lies in the insight it gives us into the probable origin of the cupreous sandstones, such as those of the Trias in England, (Alderley Edge, Cheshire), in the Kupfer-Schiefer of Germany, the cupreous sandstones of Southern France, and the interstratified cupreous coal and sandstones of Nova Scotia. In the latter case, we have strong proofs of the denudation of rocks containing copper lodes. These, with their metallic contents, being washed down into the swamp, the vegetation of which was afterwards converted into coal, gave rise to the interstratification at first so puzzling to us.

In this little Cornish Bay, we have presented to us some of the most interesting facts of Geology :—

Firstly.—The outburst of Granite and consequent harden-

ing of the sedimentary rocks surrounding it. Then the cause of the solitary hill called St. Agnes Beacon stands revealed. Next we have the plexus of Lodes and cross-courses with the curious intermingling of mechanical and chemical deposits in their contents. Then the æolian deposits, of which we think so little when examining our Triassic and other sandstones. Lastly, we obtain the absolute proof of the formation of a cupreous rock through aqueous agency.

II.

THEORIES OF VOLCANIC ENERGY,

By Thomas Brennan.

Vulcanology.—The study of the forces at work in the depths of the earth is about a century old, Spallanzani's observations on some of the Italian volcanoes, published in 1788, being the first attempt to classify the various phenomena presented by these mountains. About the same time Sir William Hamilton made a series of observations on the changes in form effected by the eruptions of Vesuvius. Von Buch, Humboldt and Abich continued these observations, but it was not until 1825, when Scrope published his " Considerations on volcanoes", that an attempt was made to reduce former observations to a system, and found a theory of volcanic energy. When the enthusiasm caused by Scrope's grand work had subsided, there was no lack of theories, but they created very little interest till Mr. R. Mallet published his remarkable " Contraction theory" in the Transactions of the Royal Society for 1873. This paper brought forth a discussion, which may be said to be still going on.

Theories regarding the Condition of the Earth's Interior.

(1). The earth may consist of a liquid kernel with a thin solid crust. (2). It may consist of a solid nucleus and an external solid crust separated by a shell of fluid matter, as held by Mr. Starkie Gardner, (3) or containing huge caverns filled with molten rock, as advocated by Mr. Hopkins. (4). *It may be at* a certain depth at a far higher temperature than

would suffice to melt any substance at the surface, but kept solid by the pressure, as maintained by the Rev. O. Fisher. (5). Dr. Sterry Hunt believes the earth to have a solid anhydrous nucleus, surrounded by a zone of hydrated rock containing the various chemical compounds thrown off by volcanoes, and in a state of hydrothermal fusion. Upon this zone rests the solid crust. (6). It may be solid from the centre to circumference, but hotter in the interior than at the surface.

If volcanoes draw their supplies of lava from an immense reservoir in the interior of the earth, their lavas should be somewhat similar in composition; those volcanoes in the same district should be all active or all dormant at the same time; the lava in all should reach the same level; we should have a volcanic tide as well as an oceanic one; and the earth would be in a state of unstable equilibrium. The astronomical arguments against a thin crust, being based upon the assumption that the passage from perfect solid to perfect fluid is sudden, are of very doubtful value. If No. 2 be correct, and the deposition of sediment caused the crust to sink into the fluid mass, oceanic basins would be permanent, an inference which seems to be opposed to the history of the cretaceous and nummulitic periods. If volcanoes draw their supplies from the caverns, alluded to in No. 3, their periods of activity and repose are unaccountable, even if we suppose, as those who uphold that theory do, that solidified materials could sink from the circumference to the centre of the earth without being re-fused, or that the caverns would be formed near the surface. If No. 4 be true, and fusion takes place by the removal of pressure, unstable equilibrium would be established, and volcanoes would follow no law of distribution. No. 5 is open to the same objections. The rate of increase of temperature with increase of depth varies from 1° for 15 feet to 1° for 200 feet, and at one place, Buda-Pesth, it was found that the temperature actually decreased below 3000 feet. This alone is sufficient to cast doubt upon the opinion that it is the approach to a highly heated nucleus which causes the rise in temperature. It has been found that in volcanic districts, or where

volcanoes have recently been active, the rise is abnormally high. As, according to Sir G. Airy, it takes heat 10,000 years to descend a mile, this heat may possibly be a remnant of former volcanic energy.

THEORIES OF VOLCANOES.—Sir Humphrey Davy supposed that volcanoes might be caused by the sea water finding access to the metals of the alkalies which he supposed to exist in an unoxidised state in the interior. Fissures would be necessary for this, and what is to produce them?

Tschermak, when it was discovered that heated substances were capable of absorbing many times their own bulk of various gases, supposed that the elements were absorbed by the first formed fluid materials, and that they are occluded or given off in cooling. These elements combine, producing the required heat and gases given off by volcanoes. That thick masses of sediment cause volcanic energy was the hypothesis adopted by Scrope and Babbage, and that by the expansion caused by this heat, elevation is produced, is the theory adopted by Captain Hutton. This cause is insufficient, but it is well attested that mountain chains are formed out of thick masses of sediment, and volcanoes arise simultaneously with them. The Alps are composed of 50,000 feet of sedimentary strata, the deposition of this was preceded by a line of volcanoes on their site while their elevation was accompanied by the formation of the European Miocene volcanoes. Mr. Robert Mallet has propounded a theory which be supposes to be capable of answering all questions suggested by a study of Vulcanology. The earth's interior, being hotter than the crust, contracts more rapidly. Being deprived of its weight it is obliged to wrinkle in following the lessening nucleus. While yet thin, this wrinkling was affected by broad folds, and the contours of our continents and oceans were established. When it had become thick the wrinkles formed mountain chains, and as the nucleus still receded the downward movement of the crust was resolved into lateral pressure causing contortion, slaty cleavage, and faults. At length, becoming too thick to find relief in this manner, the lateral pressure was used up in crush-

ing the rock thereby producing sufficient heat to cause volcanoes. Water would percolate through the crushed rock and when in sufficient quantity would, in the shape of steam, force the fused materials to the surface. As heat may be converted into chemical energy, metamorphism would take place along the lines of weakness established at an early period of the earth's history. This is the reason why volcanoes follow lines of elevation in proximity to the sea.

It is doubtful whether in this theory the machinery is sufficient for the work it has to do, but this is not the most obvious objection. Previously to the period of mountain building, which Mr. Mallet thinks may have come down to the Cretaceous period, no explosive volcanoes would exist. Yet we have evidences of them during nearly all geological epochs, even from Pre-Cambrian times (the Wrekin, &c.), while our highest mountains are of very recent date.

Le Conte has endeavoured to modify this theory by supposing that lateral pressure began before the sediment was hardened, and that lines of weakness are not determined by fractures but by the action of heat and water in softening the rocks.

It was formerly agreed by all that steam is the projectile force of volcanoes, but Prof. Prestwich* has recently announced his opinion that this steam is but a secondary product drawn first from the mass of the volcano, next from the underlying rocks and lastly from the sea. It is to be hoped this discussion will be followed up.

It is evident that we are not yet in a position to pronounce whether any of these theories, or a combination of them, will be ultimately adopted. The subject of Vulcanology seems to have reached the stage in which LYELL found the less obscure problems of physical geology, and it is very desirable that before long we may welcome the appearance of the LYELL of Vulcanology.

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* *Vide* "Some Observations on the Causes of Volcanic Action," *by* J. Prestwich, F.R.S., in British Association Reports, York *Meeting, 1881*. See also Geol. Mag., January, 1882, page 30.

LIVERPOOL GEOLOGICAL ASSOCIATION.

Field Meeting, July 8th, 1882.

Held on the banks of the River Dee, Cheshire, between West Kirby and Dawpool. Mr. D. Mackintosh, F.G.S., explained the formation of the Glacial deposits, and traced the origin and transport of some of the rocks found in the Boulder Clay.

Field Meeting, August 7th, 1882.

Held at Beeston and the Peckforton Hills. On Beeston Hill, the junction of the Keuper and Bunter Beds was observed, and in a neighbouring quarry, the joints of the Keuper were found to contain the mineral Barytes, the rock being also, in parts, impregnated with traces of Copper. Some of the party afterwards visited Peckforton Castle, and ascended the "Table Rock" and "Stannan Tor." A brief explanation of the Geological features of the locality was given by the Secretary.

Field Meeting, August 26th, 1882.

Held at Burton Point, near Neston, where a fine section occurs, showing the superposition of the Pebble Beds on the Lower Mottled Sandstone. Mr. Charles E. Miles explained the typical features of the section. The Pebble Beds are here exceedingly well represented.

Ordinary Meeting, September 4th, 1882.

Held at the Free Library, the President, Mr. Henry Bramall, M. Inst, C.E., in the Chair.

The following were elected as Members:—Mrs. John Morris; Miss Emily Moore; Miss E. Pratt; Mr. S. Henson.

Proposed as Members :—Messrs. Benjamin Biram, Assoc, M. Inst. C.E., St. Helens; H. Beasley, Acrefield House, Woolton; Bernard Conlon, 22, Mount Pleasant; Frederick P. Marrat, 21, Kinglake Street; Wm. A. Jones, 82, Laurel

Road, Edge Lane; Wm. Joinson Jones, 7, Rhiwlas Street; J. M. Kissack, 18, Queen's Road; Luke Currie, 3, Lord St.; Joseph M. Barber, 85, Premier St., Everton; and Chas. Rowett, 2, Verulam St., Liverpool.

The following were elected Auditors, (in accordance with Rule IV.)—Messrs. Anthony W. Auden and Hopkin Thomas.

DONATIONS.

"Transactions" Manchester Geological Society, Parts 16 to 18, from the Society; Annual Reports of the Chester Society of Natural Science, the Liverpool Science Students' Association, and the Atkinson Free Library, Southport, from the various Committees.

Abstract of a Paper read on—

"DIAMONDS,"

By Charles E. Miles.

The love of personal ornament is a peculiar characteristic common both to civilized man and the savage. The substances chosen by them for this object, however, are not similar; while the savage is content with such perishable materials as shells or feathers, civilized man seeks for something more durable, brilliant and rare. For this purpose, many different natural objects are utilized, some on account of their richness of color alone, but generally, the substances chosen are those which possess the qualities of hardness, transparency and brilliancy, combined with richness and depth of color. Foremost in the rank of these natural bodies is the Diamond, in which gem all the peculiar properties here mentioned are found developed in the highest degree.

One of the features about the Diamond that first attracts our attention is its extreme value, due to its rarity and the many valuable properties it possesses. We might enquire, Why is it rare? Why is it not so common as a quartz pebble? That the question is not altogether unanswerable may be gathered from the following Paper.

The Diamond belongs to the Regular or Cubical system of crystallography, and generally occurs in the form of the octahedron, dodecahedron and other forms more complex. A striking peculiarity in the crystal of the Diamond is that the faces of the crystal are curved or rounded, so much so in some instances that it resembles a little ball.

Mineral crystals occur as a rule only of small size. Excepting the minerals quartz and beryl, the crystals of which do sometimes attain considerable dimensions, most crystals are very small and often minute, even to a microscopic point. For the greater number of mineral crystals, two inches long are very large, and few exceed four inches in length. Large crystals are generally opaque. The Diamond is one of those minerals, the crystals of which are found, generally, only of small size. It has been estimated that four-fifths of the diamonds from Brazil weigh less than one carat each, (about 3 $^1/_{16}$ grains troy, or the size of a small pea), many of them being much below that. Owing to the crystallization not always being good, out of every 1,000 diamonds found 50 alone may have commercial value for ornamental purposes, hence the great value of large clear transparent diamonds.

The Diamond is almost pure Carbon, and burns at a high temperature. It has a Sp. Gr. of 3·48 to 3·55, varying very slightly, and is the hardest of all minerals; but though hard it is also very brittle. It is usually almost colorless, "pure water" diamonds being rare, but it is also found colored yellowish, red, orange, green, brown or black, and, very rarely, blue or ruby color. The Diamond has a peculiar lustre called adamantine. When rubbed it exhibits vitreous or positive electricity; at the same time it is a non-conductor of electricity, being the reverse of ordinary carbon.

A valuable property possessed by the Diamond is that of cleavage in certain directions, parallel to the faces of the octahedron. This property saves immense labour in cutting the crystal in the form known as the "Brilliant." In the "Brilliant" we have all the valuable qualities of the gem brought out to perfection, but the stone must be cut in

accordance with its refractive index and have good depth in comparison with its breadth. The index of refraction of the Diamond is 2·439, and its limiting angle is 24°13′, hence all light thrown upon its under surface at an angle of incidence greater than 24°13′ is reflected. The reflected light being decomposed and dispersed in its passage back through the crystal, the play of color known as the "fire" is thus observed.

Sir David Brewster discovered that the Diamond under the microscope exhibits numberless minute cavities containing fluids or gases, sometimes in such quantities as to render the crystal almost black. The contents of these cavities appear to have exercised pressure upon the surrounding parts of the diamond when formed. This irregularity of structure causes aberration of light, and generally renders the diamond unserviceable for optical purposes, for which otherwise it is most suitable.

When heated without access of air, the Diamond swells up and becomes a black mass. When undergoing combustion it darkens or turns black. A curious circumstance, shewn by M. Morren (Senior of the Faculty of Sciences at Marseilles), is that the Diamond appears to burn in layers, for if the combustion be arrested at any period, the form of crystallization is still displayed. This is an evidence of its infusibility, and points to the improbability of it having crystallized as fused carbon. The late Professor Gustav Rose also pointed out that the octahedral faces of the Diamond became grooved by triangular striations after burning, or on being strongly heated in air. The fact that diamonds are sometimes found having impressions of other diamonds upon the faces of the crystals has been adduced as evidence of the original pasty condition of the gem; but, no doubt, this appearance is due to secondary causes, similar to those described by Prof. Rose.

There is an impure black form of Diamond found in Brazil, called *Carbonado* or *Carbonate*, which does not occur in crystals, and which when burnt leaves a residue of about two per cent of ash. Owing to this form of carbon being as hard as the

diamond, but much tougher in texture, it is in great demand for rock boring purposes.

Diamonds appear to have been long known in India and China. The ancients were familiar with the gem, but under the name of "Adamas" they included with it other hard substances such as the Sapphire. The Diamond-districts are few in number; diamonds being found in South Africa, Hindostan, Brazil, Sumatra, Borneo, the Ural Mountains, Australia and occasionally in North America, in Georgia and North Carolina. Those discovered in Australia are very small in size, and few have been obtained from that locality. A singular fact is that for the most part Diamond-districts are also Gold-districts, proving the correctness of Pliny's remark that "the Diamond is the companion of Gold."*

In Brazil, North America, and the Ural Mountains, there is found associated with the Diamond a peculiar Sandstone, sometimes flexible in thin slabs, the flexibility being due to the binding material which holds together the fine grains of quartz. The name of *Itacolumite* has been given to this rock.

In Brazil the Diamond is also found in a ferruginous quartzose conglomerate, termed *Cascalhao*. Diamonds, however, are generally obtained from alluvial washings, but in South Africa they are now chiefly obtained from the matrix, consisting in this instance of a decomposed volcanic rock. Associated with the Diamond, in the Diamond-districts of Bahia, Brazil, the following minerals have been recognized, viz:—quartz, felspar, rutile, brookite, anatase, zircon, diaspore, magnetite, gold in grains, garnet, anhydrous phosphate of alumina and lime, silicate of yttria, &c. Emanuel states that Diamonds have been found in Brazil on the highest peaks of the Itambe, this mountain being about 5598 feet above the sea-level.†

It is highly improbable that either the Itacolumite or Cascalhao can be the true matrix of the Diamond, the Itacolumite only, perhaps, having a slight claim upon our attention in considering the various theories connected with the origin of this gem. Considerable interest, however, has been excited over the

* King—Precious Stones and Metals, p. 45.
† Emanuel—Diamonds and Precious Stones, p. 57.

Diamond-fields of South Africa, not only on account of the abundance—comparatively speaking—of diamonds found there, but also on account of the remarkable peculiarities of their situation. In fact until the last few years the origin of the Diamond has been a very speculative question, but from the nature of the matrix and character of the crystals of this mineral found in South Africa, much light has been thrown upon the subject. The experiments conducted by Mr. J. B. Hannay, F.C.S., of Glasgow—announced in the *Times*, of 20th Feb., 1880,—on the artificial production of the Diamond, give us additional light, and the entire elucidation of the question of the genesis of this mineral appears now not far distant.

Much has been written on the subject of the Diamond-fields and Geology of South Africa, but the information is in a very scattered condition, new facts being continually brought to light as the mining has progressed since 1870.

A considerable portion of the rocks of South Africa consist of an enormous series of horizontal sandstones and shales. They compose the whole of the interior, forming the high elevated plains of the Kalahari, the Free States and the Transvaal. The term "Karoo Formation" has been given to this series, from the Karoos—the immense plains of the interior. These strata are intersected by numerous trap-dykes at different angles, the igneous rock in places being intercalated with the sedimentary strata. Being horizontally bedded and much denuded, the series form table-lands and flat topped hills intersected by broad valleys. The Diamond-fields are found chiefly in the colony of Griqualand West, through which the Vaal River flows. Diamonds are found in the gravel and sandy soil forming the superficial deposits of the Vaal valley. The Vaal River gravels are very beautiful and contain pebbles of Chalcedony, Agate, red and white Carnelian, Mochastone, Semiopal. Quartz, pellucid, smoky, milky and opaque; both perfect and waterworn crystals. Amethyst. Jasper and Lydite, waterworn. Calcite, fragments. Selenite, crystals. Garnet (Pyrope), and Cinnamon-stone: fragments of garnet very plentiful, perfect crystals rare.

Chlorite. Natrolite and Mesotype, crystals and fragments. Peridot, fragments plentiful, Diopside, fragments. Tourmaline perfect and broken. Specular Iron Ore. Hepatic Pyrites, perfect. Ilmenite, waterworn fragments.*

The "pans" or "dry diggings" however, claim our chief attention, as the Diamond appears to be found there in its true matrix. The country to the south of the Vaal is mostly flat and very much coated with loose sand. Local depressions of the ground are very common in this district, some being of large size—from two to three miles in length, and the term "pans" has been applied to them. During dry seasons water that has collected is evaporated from the "pans" and a saline encrustation remains. The "pans" or "dry diggings," such as Colesburg Kopje, Du Toit's Pan, De Beer's, Bultfontein, and Jagersfontein, are all very similar in character, the contents are the same in each case and shew distinctly their igneous origin. They appear to be volcanic pipes that have burst through the surrounding shales. Each area is more or less circular in form. For the distance of one to several feet from the line of junction, the horizontal shales are bent up sharply, owing to the passage of the volcanic rock through them. On sinking into these "pipes" red sand or sandy soil is met with extending from a few inches to several feet in depth, then a layer of tufaceous lime from a few inches to 8 or 10 feet in thickness, which shades gradually into a much altered volcanic rock lying beneath. This igneous rock is of a very puzzling character. For the first 100 feet it is very friable, but the rock has a tougher texture as the depth then increases. The rock is of a greenish or yellowish colour, and for want of a better name it has been described as decomposed gabbro or euphotide. But this name is not applicable, as the rock contains no felspar, and it has been pointed out by Prof. Maskelyne that "the materials so far as they could be determined in their present altered condition were such as would not build up any of the known rocks. The absence of felspar in all the rocks but

* Prof. T. Rupert Jones, F.G.S., Geol. Mag., 1871, Vol. viii, p. 55.

one was singular."* The rock in the "pipes" or "pans" has been examined by Prof. Maskelyne, who describes it as "exhibiting the character of a bronzite rock converted in greater part into a hydrated magnesium silicate, which has the chemical character of a hydrated bronzite.†" The component minerals of the rock have been analysed by Dr. Flight. Some of them appear to be new species of the pyroxene group. From the surface down the following minerals are met with in the altered rock, viz. :—Garnet, Calc-spar, Mica, Bronzite, Augite, Diopside, Diallage, Iron Pyrites, Ilmenite, &c. Also "scattered throughout the mass are particles, fragments and huge masses of shale, nodules of dolerite, occasional fragments of chloritic schist, micaceous schist and gneiss. The principal foreign ingredient is the shale." "The entangled blocks of shale and sandstone are frequently altered, the latter sometimes into quartz rock. Disseminated throughout the decomposed rock, Diamonds are met with from over 150 carats down to minute ones only 100th of a carat in weight. Many of the diamonds are beautifully formed crystals, but a large per-centage consists of fragments and broken crystals, and, strange to say, the corresponding pieces are *never* found."‡ The diamonds found in each of the "pipes" have a distinct character from those found in the others. At Bultfontein the diamonds are very small but numerous, and are remarkable for the absence of color. At Du Toit's Pan, large diamonds of a yellowish color are found.

One of the most remarkable facts bearing upon the subject of the genesis of the Diamond in South Africa has recently been brought forward by Mr. E. J. Dunn. He says "that at all the old mines (Kimberley, De Beer's, Du Toit's Pan, and Bultfontein), there are exposures of considerable deposits of black carbonaceous shale underlying the surface beds of

*Quart. Jour. Geol. Soc. of London, 1874, Vol. xxx, p. 60. † Ibid, p. 407.

‡ Ditto, p. 54, Paper by E. J. Dunn.

grey shale." "At Kimberley mine the surface grey shales are from 40 to 50 feet thick, and underneath are black carbonaceous shales, for the most part arenaceous and more than 100 feet thick."* Thin seams of impure coal, full of pyrites, occur in the black shales, and the shales are very combustible. There seems to be some connection between the diamonds and the black shales, as the diamonds are more plentiful and of better quality where the zone of black shales occurs.

Taking in connection the mode of occurrence of the Diamond in South Africa, together with the recent interesting experiments of Mr. Hannay on its artificial production, we now have a clue as to the probable method employed by Nature in producing the Diamond. Mr. Hannay,† while pursuing his researches into the solubility of solids in gases, noticed that silica, alumina, oxide of zinc, &c., which ordinarily are insoluble in water at ordinary temperatures, dissolve to a considerable extent when treated with water-gas under a very high pressure. He thought if he could find a gaseous solvent for carbon, the carbon would crystallize as Diamond, on removal of the solvent or lowering of the temperature, as gaseous solutions nearly always yield crystalline solids by this means. Ordinary carbon such as charcoal, lampblack, or graphite, could not be acted upon in this way, chemical action taking place instead. Advantage was taken of the fact that when a gas containing hydrogen and carbon in combination is heated under pressure in presence of certain of the alkali metals, such as magnesium, lithium, &c., a compound is formed by the metal uniting with the hydrogen, the carbon being liberated. Nascent carbon, however, will not crystallize, it requires a solvent. After many experiments, a strong iron tube containing a mixture of four grams lithium, 10 per cent paraffine spirit, and 90 per cent of rectified bone oil distillate, was strongly heated in a furnace. The bone oil distillate was the menstruum employed as the carbon solvent,

*Quart. Journ., Geol. Soc. of London, 1881, Vol. xxxvii, p. 609.

†Proc, Royal Soc., London, 1880, p.p. 188 and 450,

and, on the cooling of the tube, transparent octahedral crystals, having curved faces, were obtained in a black matrix. On examination, and applying the proper tests, the crystals proved to be veritable diamonds having a Sp. Gr. of 3·5.

We have yet to learn the chemical process entailed in the production of the natural diamond. Hannay's experiments shew us that carbon, in order to crystallize, requires a solvent, the solvent in his process being a gas. Then what solvent has Nature employed? There remains to be seen whether diamonds are to be found in the South African "pans" below the junction of the igneous rock with the carbonaceous shales. That the diamonds in the volcanic pipes have been carried upward with the molten rock is clear from the fact that many of them are shattered crystals, the fragments being disconnected and not found together. They also shew that after formation they have been subjected to incipient combustion, as many of them bear upon their octahedral faces the triangular indentations pointed out by the late Prof. Rose as being the result of such a process. Then, have the diamonds really any connection with the carbonaceous shales? The evidence generally points to the affirmative. But may they not have been formed in Nature's great laboratory deep in the earth, and brought to the surface by an outburst of ultra-basic lava. Further evidence is still required to confirm the facts already brought to light.

Whatever the circumstances are by which Nature has produced the Diamond, those circumstances appear to be exceptional, and the conditions rarely meet. Hence the Diamond is of necessity found of rare occurrence.

LIVERPOOL GEOLOGICAL ASSOCIATION.

18*th September*, 1882.

An Excursion in conjunction with the Liverpool Science Students' Association, took place at St. Helens, when the Sankey Brook Collieries were visited, by permission of Mr. Henry Bramall, who, with his son, Mr. Ernest Bramall, conducted the party over the Colliery, to inspect the machinery employed for draining and ventilating the mines, winding the coal and screening and preparing it for market. The descent of the pit was also made, in order to observe the mode of occurrence of Coal seams, and the methods employed in getting them.

28*th September*, 1882.

An Excursion took place on above date at Chester, where, by the courteous permission of the Chester Society of Natural Science, the valuable Museum of that Society was thrown open to the inspection of our members. An examination of the various Natural History and Archæological collections displayed there afforded great pleasure to the visitors, and the excellence of the arrangement, especially in the departments of Geology and Conchology, attracted great attention. In the evening the members accepted the kind hospitality of the Chester Society, and assembled for Tea in the Town Hall, where, at a later hour, a Conversazione was held, at which the presentation of the Society's "Kingsley Memorial Medal," and other Prizes, took place.

END OF VOLUME II.